THE DRESBACH FORMATION OF MINNESOTA

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THE DRESBACH FORMATION OF MINNESOTA

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BULLETIN
of the
Buffalo Society of Natural Sciences

VOLUME XIV No. 2

The Dresbach Formation of Minnesota

By Eunice Peterson

Introduction

The Dresbach sandstone is one of the formational divisions of the St. Croixan Series of the Upper Mississippi Valley which has long been recognised by the Geologic Surveys of Wisconsin, Iowa, and Minnesota. It is included in practically every published section of this series that has appeared since its introduction into the literature in 1888 by N. H. Winchell. It is named for the little town in Winona county, Minnesota, where it was being quarried for use as a building stone. However, in recent years, as the Upper Cambrian rocks of this region have received more attention, a number of changes in classification have been suggested. Although the name Dresbach has been retained, there is considerable variation in the types of deposits referred to that formation. The name has been used to designate some typically marine sediments and some said to be largely aeolian; it has been used for unfossiliferous as well as for abundantly fossiliferous deposits which may or may not be contemporaneous. With a desire to discover whether so much variation really exists in a single formation, and just what should be included under the formation name Dresbach, the present study was undertaken.

The summers of 1923 and 1924 were spent in detailed stratigraphic studies of the entire St. Croixan Series exposed in the valleys of the Mississippi and St. Croix Rivers. Several weeks of the summer of 1925 were devoted to an intensive study of the Dresbach sandstone itself at the type locality and at other Minnesota outcrops; while the summer of 1926 was devoted largely to localities in western Wisconsin from which the Dresbach and its underlying and overlying formations have been reported or described. This treatise will, therefore, include a description of the Dresbach sandstone as it occurs at the type locality, a discussion of its relations in general to the underlying and overlying formations, and a comparison of the Minnesota and the Wisconsin sections.

Identifications of the Dresbach have been made entirely upon the basis of field examinations and paleontological studies. A recent

petrographic study of the Cambrian sandstones of the same region gives evidence that correlation by petrographic methods is unsatisfactory.[1]

The underlying and overlying formations were given careful study at their type localities as well as in sections where they are exposed with the Dresbach, in order to limit the Dresbach itself as accurately as possible.

Since it is proposed[2] to use the Mississippi Valley section of the Upper Cambrian as the standard St. Croixan section to which all other formations of that age in North America may be referred for correlation, it seems imperative that its formational divisions be accurately described and carefully limited. The confusion incurred by various connotations of the Dresbach, one of the key formations in this classification, made a careful study and redefinition of that formation appear to be desirable.

The writer wishes to express her sincere appreciation to Dr. C. R. Stauffer for his unfailing interest and encouragement in the study of this problem and for much constructive criticism of the work; to Dr. E. O. Ulrich, who kindly read the manuscript, for excellent suggestions; and to Dr. F. F. Grout for his helpful advice.

Geography of the Region

Location. Although the Dresbach sandstone is a persistent formation over southwestern Minnesota, central and southern Wisconsin, northern Iowa and northern Illinois, it is known from outcrops in only a small part of this area. The region in which this study was pursued, was chosen particularly to include the type localities of the Franconia, the Eau Claire, and the Mt. Simon sandstones—the formations that lie above and below the Dresbach—as well as the type location of the Dresbach formation proper. These type localities, namely, Franconia, Minnesota, Eau Claire, Wisconsin, and Dresbach, Minnesota, are so situated geographically that they form the apices of a triangular area of approximately 4000 square miles. (See Plate 1.) This area, in which a large number of the outcrops consist of strata from one or more of these formations, formed the principal field of investigation.

The Minnesota-Wisconsin boundary was traversed from Taylors Falls, Minnesota, along the St. Croix and Mississippi Rivers to the Iowa line. The river bluffs and ravines afford some excellent outcrops, as do the recent road cuts made in the construction of Minnesota State Highway No. 3, and the railroad cuts along the Chicago, Milwaukee and St. Paul right-of-way. Both the highway and the

[1]Graham, W. A. P., A Petrographic Study of the Cambrian Sandstones of Minnesota and Wisconsin. MS 1927.

[2]Resser, C. E., Lecture to the Geology Club, Princeton University, November, 1926

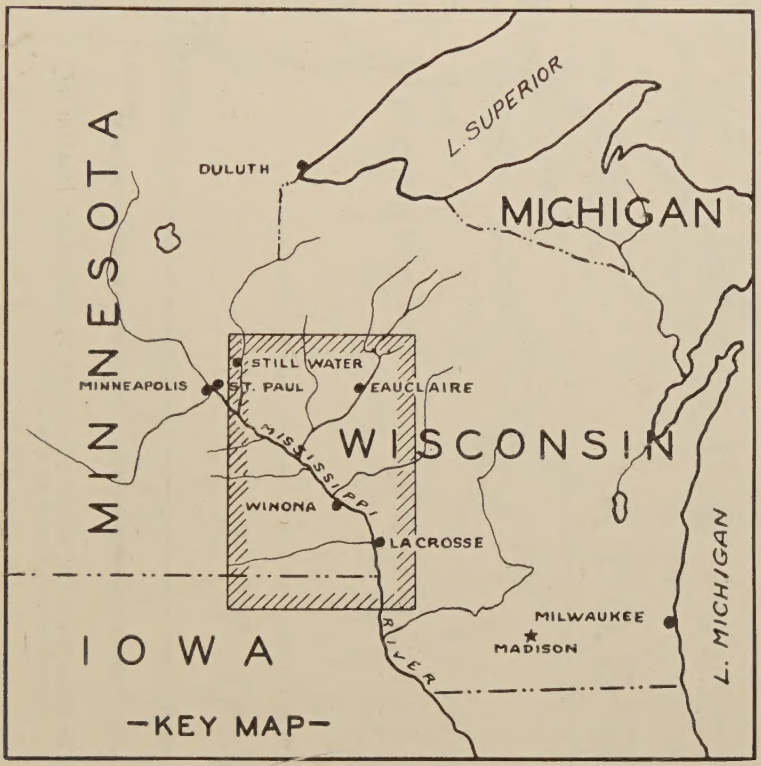

FIGURE 1.—*Sketch map indicating the area in which the Dresbach formation was studied.*

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railroad follow the Mississippi River closely, and are responsible for some very good exposures along the base of the bluffs where the country rock would normally be covered by vegetation. In addition, the Willow River, tributary to the St. Croix, and the Black and Chippewa rivers, and more especially their numerous tributaries have served the geologist well in uncovering the country rock. At a few places, notably Dresbach and Dakota, Minnesota, and Eau Claire and Colfax, Wisconsin, quarries have served to expose the rocks in places where they would otherwise have been difficult of access.

Topography. From the St. Croix Valley down the Mississippi River to a line following the course of the Chippewa River, though somewhat south of it, the region studied lies within the glaciated portions of Wisconsin and Minnesota. The topography is largely determined by the glacial deposits, chiefly terminal and ground moraine types. The country is undulating, and particularly near the St. Croix River it displays the knobs and kettle lakes so characteristic of the terminal moraine of the Wisconsin drift. The glacial deposits are as a rule about 100 feet thick, and exceed that figure considerably in places. In general they thin somewhat toward the south. Outcrops of pre-Pleistocene sediments are most common where the rivers and smaller drainage channels have cut through the drift and penetrated the country rock.

South of the Chippewa River the rugged "driftless" area is encountered. Although more of the country rock is exposed, the outcrops are chiefly high in the hills. The slopes of a large number of the hills, with the exception of those slopes close to the Mississippi, are for the most part made up of Dresbach sandstone which is capped with the more firmly cemented basal beds of the Franconia sandstone. As a rule, however, only the Franconia beds are exposed; while the Dresbach sandstone is covered with vegetation and is nearly everywhere inaccessible for study unless it has been disclosed by youthful streams or by human agencies.

Differences of elevation of over 500 feet occur within the area. The bluffs along the Mississippi and St. Croix Rivers increase in height from about 200 feet at St. Croix Falls, the northwestern limit of the area, to 650 feet at Trempeleau, near the southern limit. To the north they decrease in height to 200 feet or less in the vicinity of Eau Claire. Elevations within the area range from 628 feet to over 1200 feet above sea level.

Drainage. The gorge of the Mississippi River and the valleys of its principal tributaries north of La Crosse, Wisconsin, proved fertile fields for the investigation of the lower formations of the St. Croix Series.

The Mississippi River flows through a steep-walled trench of varying width, which forms the western boundary of Wisconsin and

the eastern boundary of Minnesota. Its bluffs, 230 to 650 feet high, border bottomlands ranging in width from 1 to 6½ miles. "These bluffs are exceedingly steep, descending more than 500 feet near Trempeleau, for example, within a distance of 800 feet. In fact a portion of each bluff is likely to be a precipice. It is this retention of steep cliffs and precipices on the walls of the gorge that lead us to call it a gorge and to classify it as young. In most places the gorge wall consists of steep slopes on the weaker rocks [of which the Dresbach is one] and precipices where the more resistant layers of sandstone or limestone come to the surface."[3]

The floodplain of the river occupies most of the bottomland, and along its sides usually close to the bluffs is a conspicuous series of terraces. Although the terraces do not extend continuously for more than a few miles in any case, they furnish the sites for most of the important cities and villages along the river, and serve to conceal the lower 20, 30, or even 50 or more feet of country rock, which in many places is doubtless Dresbach in age.[4]

The gorge in which the Mississippi now flows was occupied by a larger stream during the Glacial period. This stream may have deepened the pre-glacial valley somewhat, and certainly deposited a great thickness of sand and gravel in it, thereby elevating the river to a level where the bases of the bluffs are farther apart than they would be if the river were flowing on the rock floor 100 to 200 feet below. This filling with glacial debris accounts for the seeming incongruity in the size relationship between the present stream and its gorge.

From its confluence with the Mississippi to St. Croix Falls, Wisconsin, the northernmost point studied, the St. Croix River forms the Minnesota-Wisconsin boundary. It flows through a gorge quite similar to that traversed by the Mississippi, though its floodplain is not so wide, and its bluffs are rarely over 250 feet in height. A considerable number of very good Upper Cambrian sections are exposed by the St. Croix and its tributaries. Among those of particular interest in this study are the Dresbach sandy shales at St. Croix Falls, the type section of the Franconia sandstone on Lawrence Creek at Franconia, Minnesota, and an excellent section of the Dresbach at Willow River dam, near Hudson, Wisconsin.

The Chippewa River west of Chippewa Falls flows through a region in which the country rock is St. Croixan sandstone, and the surface formations are pre-Wisconsin drift. The wide valley is bordered chiefly by low bluffs with few rock outcrops, their gentle slopes in most cases being covered with vegetation. Outcrops are more numerous in the gorges of the tributaries of the Chippewa

[3]Martin, L., The Physical Geography of Wisconsin, Wis. Geol. and Nat. Hist. Survey, Bull. 36, p. 134, 1916.
[4]Martin, L., ibid. figure 46, and 50.

River. The Red Cedar River, the Eau Galle River, and Rock Creek all furnish excellent sections. The Chippewa River is tributary to the Mississippi entering it at the lower end of Lake Pepin. The lake is made by the damming back of Mississippi waters by the Chippewa River delta.

West of Black River Falls, the Black River flows through the more rugged "driftless area." Its headwaters are in the glaciated region to the northeast, and it was at one time fed by the melting ice sheet and carried a much greater volume of water than it does at the present time. As a result vast quantities of sediment were transported by the river, and numerous gravel terraces now line the broad valley of the lower Black River.

Beaver Creek, entering the Black River near Galesville, Wisconsin, exposes the Dresbach sandstone to advantage near Galesville and Ettrick. The Trempeleau and Buffalo Rivers likewise flow through hilly country of the "driftless area."

In Minnesota the larger tributaries to the Mississippi River have no really good Dresbach sections, and therefore will be omitted from this discussion.

In summary it may be said that all the larger river valleys of this area are in the stage of youth, in the cycle of erosion. Having served as drainage channels for the melting glaciers during late Pleistocene time, they now flow through valleys that appear too large for the present streams—valleys that have been built up by the deposition of glacial sediments and are characterized by numerous gravel terraces. They are bordered by bluffs with steep to gentle vegetation-covered lower slopes, and in many cases steep, bare summits. The smaller streams, tributary to the larger rivers, are even more youthful, having developed miniature canyons in parts of their courses, thereby disclosing almost complete vertical sections of the country rock.

General Geology of the Region

The oldest rocks in the area are the Laurentian and Huronian crystalline rocks, chiefly igneous, that are present where they have been brought to the surface by erosion in the valleys of the Black and the Chippewa Rivers at Black River Falls, and at Chippewa Falls, Wisconsin. Their westernmost outcrops serve to limit the area studied on the northeast. Similarly the Keweenawan diabase flows limit the area on the northwest, where they outcrop at Taylors Falls, Minnesota, and at Interstate Park opposite St. Croix Falls, Wisconsin. Outcropping north of this area, and interbedded with these diabase flows, is a great series of sandstones and shales, which underlies a large part of this region and is known in Minnesota as the Red Clastic Series. This series is over 2000 feet thick at Stillwater,

Minnesota, where a deep well has been drilled into the underlying diabase, though it is absent 60 miles east of there at Eau Claire, where the Mt. Simon formation, which is considered Upper Cambrian[5] in age, rests directly on the pre-Cambrian granite. The thickness of the Red Clastic Series varies widely, owing to the extreme irregularity of the surface on which it was deposited. These Keweenawan sediments and flows have been considered late Proterozoic (Algonkian) in age; but a recent discovery of Cambrian fossils in the clastic rocks[6] leads to the conclusion that they are really the basal formations of the Paleozoic group.

The St. Croix Series over a large part of the area rests upon sandstones of the Red Clastic Series. The nature of the contact is uncertain, as it is not known to be exposed at the surface. In the vicinity of St. Croix Falls there is an unconformity between the St. Croix formations and the Keweenawan diabase; while in the northeastern part of the area a much greater period of time is represented by the unconformity between the basal bed of the St. Croix Series and the Laurentian and Huronian crystalline rocks. A record of apparently continuous sedimentation in the shallow Upper Cambrian Sea is found in this succession of coarse to fine, multi-colored sandstones and sandy shales. Although minor changes in the conditions of sedimentation were responsible for the differences in the lithologic character of the rocks, the changes were seldom abrupt, and complete gradation between the different types of sediments is usual.[7]

Subsequent sedimentation recorded in this area includes the Prairie du Chien (Lower Magnesian) series, the St. Peter sandstone, and the Platteville-Decorah-Galena group, which are separated by erosion intervals. Outcrops of the Prairie du Chien are common along the Mississippi and St. Croix Rivers, resistant dolomites capping the bluffs and forming, with the Jordan sandstone, their castellated summits. These Paleozoic formations overlying the St. Croix series are present in this area only at some of the highest points in Pierce and St. Croix counties, Wisconsin.

So far as is known, there is no representative of any formation in this region between the Ordovician and the Pleistocene. During the latter period, there were at least two glacial advances over the northern part of the area. Wisconsin glacial deposits are present

[5]Walcott, C. D. Cambrian Geology and Paleontology, II.—Dikelocephalus and Other Genera of the Dikelocephalinae. Smithsonian Misc. Collection, Vol. 57, No. 13, p. 354, 1914.

[6]Stauffer, C. R., Age of the Red Clastic Series of Minnesota, Geol. Soc. Am. Bull., Vol. 38, pp. 469-477, 1927.

[7]This apparent continuity would lead the observer to the conclusion that sedimentation in this region had been virtually continuous during St. Croixan time. However, E. O. Ulrich has pointed out the objection that the few hundred feet of sandstone between the base of the "Eau Claire" and the base of the Franconia of Wisconsin are represented in the Appalachian Valley by thousands of feet of calcareous deposits with the *Cedaria* and *Crepicephalus* faunas in the lower fourth and pre-Franconia faunas that do not occur in Wisconsin in the upper three-fourths.

only along the St. Croix River; while the pre-Wisconsin Drift covers all the area to the south of the Chippewa River. Deposits of the earlier glaciers are chiefly ground moraine and outwash types; while those of the Wisconsin ice-sheet are principally those of the terminal moraine.[8] Prior to Pleistocene glaciation, and possibly starting in the Cambrian, gentle crustal movements caused a slight flexure of the sedimentary series in the central part of western Wisconsin and southwestern Minnesota. This flexure took the form of a broad anticlinal fold, which pitches slightly to the southwest. It is thought that Dresbach, Minnesota, is close to the axis of the fold, as near there the lowest strata of the St. Croix sandstones in Minnesota are found. From this point, the Dresbach sandstone decreases in the exposed thickness to the northwest, south, and southwest, where within a few miles it dips under the more recent sediments. To the north and east it is found higher and higher in the bluffs until its place is taken by the underlying formations, the Dresbach itself having been largely removed by erosion, because of its greater elevation in this part of the area.

Stratigraphy

Classification. *A Historical Summary.* A number of early writers have suggested that the "Lower Sandstone" which is found in the Upper Mississippi Valley was probably the equivalent of the Potsdam (Upper Cambrian) of New York. In 1843 James Hall noted that from their stratigraphic positions these two formations might well be correlated.[9] Later in his "Report of a Geological Reconnaisance of the Chippewa Land District of Wisconsin . . . " (1848) Owen suggested this correlation. The similarity in the two series paleontologically is such that they were generally accepted as identical in age. Where undifferentiated, the Upper Cambrian sandstones of the Mississippi Valley were frequently referred to in the older literature as Potsdam Sandstone.

St. Croix as a formation name was proposed by N. H. Winchell,[10] in 1873, for the fossiliferous sandstones underlying the Oneota dolomite of the Upper Mississippi Valley. Walcott, while correlating them with the Potsdam of New York, because of the similarity of their faunas, retained the name St. Croix for these formations in Minnesota, Wisconsin, and Iowa.[11] More recently[12] Ulrich suggested that the name St. Croix be dropped as a series name

[8]Steidtmann, E., Limestones and Marls of Wisconsin, Geol. and Nat. Hist. Survey of Wisconsin, Bull. 66, plate 1. (1924)

[9]Hall, James, Natural Hist. of New York, Pt. IV, Geology, p. 27, 1843.

[10]Winchell, N. H., Revision of the Stratigraphy of the Cambrian in Minnesota, Geol. and Nat. Hist. Survey of Minnesota, 14th Annual Report, pp. 336-337, 1885-86.

[11]Walcott, C. D., Correlation Papers—Cambrian, United States Geological Survey, Bull. 81, p. 245, 1891.

[12]Ulrich, E. O., Revision of Paleozoic Systems, Bull. Geol. Soc. of Am., Vol. 22, Pl. 27 facing page 608, 1911.

for these particular upper Cambrian formations, in favor of using the term *St. Croixan* to designate the entire Upper Cambrian epoch or series. This suggestion was accepted by the United States Geological Survey, and the name St. Croixan is found in place of Saratogian for the Upper Cambrian Series in its classification as given in the recent (1925) "Geological Time Classification of the United States Geological Survey Compared with Other Classifications."[13]

The first attempt to subdivide the St. Croix Series of the Upper Mississippi Valley into its component formations was made by Owen.[14] In his explorations along the Mississippi, Chippewa, Black and St. Croix Rivers, Owen observed outcrops at various places and attempted to make from them a generalized section of the series. Recognizing that differences in the lithology of the several formations were insufficient for correlation purposes, and finding the trilobites to be by far the best guides, he made his divisions almost solely on the basis of paleontology.[15] Although his classification and correlations naturally fall short of perfection, his method has not been materially improved. He divided the series into six trilobite beds, numbering them from one to six, beginning with the lowest.

Working in Wisconsin, in 1877, Wooster[16] recognized certain horizons in the Potsdam of the west-central part of the state which he designated as follows: (1) Eau Claire Grit, (2) Eau Claire Trilobite Bed, (3) Hudson Trilobite Bed, (4) Line of Junction with the Lower Magnesian limestone. However, it is clear that he did not consider these divisions as belonging to separate formations, but rather as horizons within one formation.[17]

In the same year, Irving[18] divided the series into formations based on the exposures around Madison, Wisconsin. He, however, did not extend the "Potsdam" to the lower Magnesian, but placed his new formations between them thus:

St. Peter Sandstone
Lower Magnesian
Madison Sandstone
Mendota Limestone
Potsdam Sandstone

Having previously described formations within the St. Croix Series of Minnesota[19] from Jordan, St. Lawrence, and Dresbach, Minnesota, in 1888, N. H. Winchell suggested the following classi-

[13]Wilmarth, M. Grace, U. S. Geol. Survey Bull. 769, plate I, 1925.
[14]Owen, David Dale, Geological Survey of Wisconsin, Iowa, and Minnesota, pp. 52-53, 1852.
[15]Owen, David Dale, ibid.
[16]Wooster, L. C., Geology of Wisconsin, Vol. IV, p. 109, 1877.
[17]Wooster, L. C., ibid. pp. 106, 109, 112, 117, and Plate VI.
[18]Irving, R. D., Geology of Wisconsin, Vol. II, p. 525, 1877.
[19]Winchell, N. H., Geol. and Nat. Hist. Survey of Minnesota, 2nd Annual Report, pp. 149, 173, 1873.
Winchell, N. H., Geol. and Nat. Hist. Survey of Minnesota, Final Report, Vol. I, pp. 178-179, 1884.

fication of the formations of this series, and their correlation with the Wisconsin section:[20]

Main Body of Limestone (Oneota)		
St. Croix	Jordan Sandstone (Madison of Wisconsin)	Potsdam of Wisconsin
	St. Lawrence Limestone (Mendota of Wisconsin)	
	Shales	
	Dresbach Sandrock	
	Shales	
	Hinckley Sandrock	
	Red Shales and Sandrock passing into the cupriferous	

In 1897, after a detailed study of the region around the Dalles of the St. Croix, Berkey described a new formation, the Franconia, and made the following classification, which is similar to that used by the Minnesota Geological Survey at the present. For the sake of completeness, his entire classification which includes the lower Ordovician formations is given.[21]

Magnesian Series (Hall and Sardeson)	Shakopee dolomite			
	New Richmond sandstone			
	Oneota dolomite			
	Jordan sandstone			
	St. Lawrence dolomites and shales			
Basal Sandstone Series (Modified from Norton)	3. Franconia sandstone (100 feet)			The St. Croix Formation (Winchell)
	2. Dresbach shales (150 feet)	*Obolella polita* zone	Green sands and shales	
		Lingulepis pinnaeformis zone	Calcareous and pyritiferous shales	
	1. The lowest formation of this series is not exposed in the Dalles area, but it includes the lowest sandstone beds and possibly also the "Hinckley sandstone," (0 to 1,000 feet)			

The Hinckley sandstone of Winchell's and Berkey's classifications and the underlying sandstones and shales are now included as members of the Red Clastic Series of the Minnesota Geological Survey, and are believed to be of Middle Cambrian age.

Ulrich has suggested a further subdivision of the sediments that underlie the Dresbach and rest on formations that are pre-St. Croixan in age. In 1914, when Ulrich's work was still in manuscript form, Walcott included these new formations, namely the Eau Claire and the Mt. Simon, in his "Provisional Classification of the Upper Cambrian," which is reproduced here:[22]

[20]Winchell, N. H., ibid., Vol. II, pp. XXI-XXII, 1888.
[21]Berkey, C. P., Geology of the St. Croix Dalles, Am. Geol., Vol. XX, p. 377, 1897.
[22]Walcott, C. D., Cambrian Geology and Paleontology II, Smithsonian Misc. Collection, Vol. 57, No. 13, p. 354, 1914.

Provisional Classification of Upper Cambrian

	Formations	Lithological Characters
Upper Cambrian (St. Croixan)	Jordan 60-80′ (Winchell 1874)	Heavy bedded soft, rather coarse-grained, yellowish sandstone.
	St. Lawrence 120′ (Winchell 1874)	Soft fine-grained brown, red, green or ash-colored sandstone often dolomitic near top. Yellow and ash-colored argillaceo-calcareous, thin-bedded rock near middle, and green sands inter-bedded with yellow sandstones in lower third.
	Franconia 85′ (Berkey 1898)	A series of thin and thick-bedded usually soft sandstones with much green material throughout or only in portions. The upper fifty feet often harder than the underlying beds and containing a considerable fauna, especially species of *Conaspis*. In many localities other fossiliferous beds occur in the central and lower portions.
	Dresbach 100′ (Winchell 1874)	Massive-bedded, rather coarse-grained sandstone, with a thin bed of shale at the base and shaly sandstone near the middle. Fossils almost entirely of shells of *Dicellomus* and *Lingulella*.
	Eau Claire About 100′ (Ulrich MS. 1914)	Mostly thin-bedded, in part shaly sandstone, with many fossiliferous layers, including Owen's Menomonie and Wooster's Eau Claire trilobite zones. Usually a coarse white friable sandstone with *Dicellomus* and *Lingulella* at the base. Numerous characteristic trilobites, *Crepicephalus iowensis* being one of the best of the guide fossils.
	Mt. Simon 235′ (Ulrich MS. 1914)	A series of coarse sandstones and grits resting on pre-Cambrian granite. About 225 feet are shown in the bluffs at Eau Claire and 50 feet of the base at Chippewa Falls, Wisconsin. Except *Scolithus* borings no fossils have been found.

The Mt. Simon and Eau Claire formations, as described here, apparently include Wooster's Eau Claire Grit, and Eau Claire

Trilobite Bed[23] respectively, horizons which had in the meantime been ignored by the Geological Survey of Wisconsin.

Recent detailed studies of the St. Croix Series in Wisconsin have resulted in a more complex classification. In 1924 Ulrich published [24] a "Geologic Column for Wisconsin with Correlation Table for the Paleozoic Era," which embodies his conception of the Cambrian section of Wisconsin. His classification, which has been accepted by the Geological Survey of Wisconsin, [25] follows:

Cambrian

Provisional Classification of Upper Cambrian

General Time Scale	West Wisconsin	
Jordan (Minn. 80 ft. ss.)	Jordan ss. (75 ft.)	
Trempeleau (Wis. 125 ft. sh. and ls.) (=St. Lawrence of Ulrich, 1914)	Norwalk ss. member (50 ft.) Lodi Shale (50 ft.) St. Lawrence ls. (25 ft.) Shale (local 20 ft.)	
Mazomanie (Wis. 150 ft. dol. ss.)	Absent	
Franconia (Minn. 125 ft. gr. ss., sh. and ls.)	Upper Greensand (54-70) Yellow ss. (40-45) Lower Greensand (40) Micaceous sh. (15) Ironton ss. member (15)	120 ft. to 170 ft.
Dresbach (Minn.)	Dresbach ss. 40-250 ft.)	
Eau Claire (Wis.)	Eau Claire sh. (200-300 ft.)	
Mt. Simon (Wis.)	Mt. Simon ss. (100-200 ft.)	

The Geological Surveys of Iowa and Illinois to whom the St. Croix Series is known chiefly from well records, as it is rarely exposed at the surface, attempt to distinguish only three formations, —the Jordan, the St. Lawrence, and the Dresbach.

The Minnesota Geological Survey also uses a simpler classification than does Wisconsin:[26]

St. Croixan	Jordan sandstone St. Lawrence formation Franconia sandstone Dresbach sandstone Eau Claire (?) shale
Red Clastic	Hinckley sandstone Unnamed shales and sandstones

[23]Wooster, L. C., Geology of Wisconsin, Vol. IV, pp. 109-110, 1877.

[24]Ulrich, E. O., Notes on New Names in table of formations and on physical evidence of breaks between Paleozoic systems in Wisconsin, Trans. of the Wis. Acad. of Sci., Arts, and Letters, Vol. XXI, pp. 82-83, 1924.

[25]Steidtmann, Edward, Limestone and Marls of Wisconsin, Wis. Geol. and Nat. Hist. Survey, Bull. 66, pp. 26-27, 1924.

[26]Stauffer, C. R., The Jordan Sandstone, Journal of Geology, Vol. XXXIII, p. 700, 1925.

The Dresbach Sandstone. *Original Description.* The Dresbach as a distinct formation was given a place in the classification of the St. Croix Series by N. H. Winchell, in 1888. This classification was published in the "Final Report of the Geology of Minnesota," Vol. II, pp. XXI-XXII, and is reproduced on an earlier page. However, in Volume I of the same series of reports, published four years earlier (1884), Winchell gives the following general section of the St. Croix sandstone in Winona County,[27] of which he says, "Some of these parts, and probably most of them, extend, without much variation, throughout the southeastern part of the state where this sandstone appears."

Section I

General Section of the St. Croix Sandstone

1. Argillaceous, siliceous dolomitic beds, forming the transition layers between the St. Croix and the St. Lawrence. (Oneota.) Generally fine-grained, but embracing some thin strata that consist of coarse, loose quartz sand. These embrace a thickness of forty to fifty feet.

2. Concretionary sandstone. This has many nodules, and even continuous layers of concretionary rock. These lumps are sometimes very fine, no larger than peas, and sometimes they swell out so as to be a foot or more in thickness, constituting nearly continuous layers, and making a very firm rock, since they consist entirely of cemented grains of silica, the cement itself being apparently siliceous . . . twenty-five to thirty feet.

3. Loose, mssive sand, more or less stained with iron, generally turfed over, or covered with timber. In favorable situations this loose sandy rock forms a line of constant exposure, since its face becomes nearly perpendicular; the overlying quartzitic beds protecting it from denudation. The thickness of this member amounts to forty or fifty feet.

4. Argillaceous and siliceous beds much like No. 1, embracing the quarries at Lake City and at Hokah, generally greenish and often sandy, with remains of trilobites and graptolites. The shaly portion of these beds embraces a large percentage of lime. Thirty to forty feet.

5. Crumbling sand, about fifty feet.

6. Shales and shaly sandrock, generally hid, about eighty-five feet.

7. Sandrock quarried by Tostevin at Dresbach;[28] including at least one shale bed of six feet in its lower portion, which is generally spring-bearing along the foot of the bluffs; 120 to 150 feet.

[27]Winchell, N. H., Final Report, Minnesota Geol. Survey, Vol. 1, p. 258, 1884.

[28]Unfortunately, Winchell does not mention the presence of fossils in the quarry rock. (No. 7.) The fact that in studying the Dresbach formation he was chiefly concerned with its suitability for building purposes doubtless explains his neglect to mention their rather limited numbers in various beds throughout the formation. That he was aware of their presence is practically certain, for in the Museum of Geology in Pillsbury Hall, University of Minnesota, there are three fossiliferous sandstone blocks which were presented by the owner of the quarries at Dresbach at the time that Winchell was State Geologist and had charge of the Museum. They bear the Museum numbers 4871 and 4872 and are listed in the Museum Register as "Dresbach (Minnesota) sandstone, Dresbach, Minnesota, Presented by J. F. Tostevin of St. Paul," and the entry is dated 1882. It can scarcely be doubted that these blocks are actually samples of the Dresbach as originally defined. On the other hand, Winchell's mention of the fossils in No. 8 was inevitable as they are exceedingly abundant, and are really the most striking characteristic of the bed.

8. Shales and shaly sandrock, very fossiliferous; extending to the water level at Dresbach, and including a conglomerate bed of four inches; ten to fifteen feet.

9. Gray sandrock, penetrated by the Winona Mining Company at Dresbach below the level of the Mississippi at least twenty feet.

10. At Dresbach the Davis brothers drilled for coal (!) a few years ago to the depth of 116 feet below the depot level, and found all the way nothing but shale and shaly sandrock alternating. Hence, add for Davis' drill, shales and shaly sandrock below all the above; sixty-eight feet.

Total thickness of the St. Croix in Winona county, 488 to 558 feet.

No. 8 above, contains what may be pteropodous forms, also some that may be orthoceratitic, and fragments of trilobites, and numerous specimens of *Lingula*. One bed of about sixteen inches at Dresbach, is largely made up of linguloid shells. It is fragile. The shales, which are bluish, contain numerous beautiful specimens of mudcracks, and of stems of fucoids. The conglomerate, which is in No. 8, is composed of fossiliferous pebbles of a gray sandstone which is apparently only hardened pieces of rock like No. 9, or like No. 7, and is almost quartzite, showing some mica scales.

The Dresbach sandstone as classified by Winchell was evidently intended to include No. 7 of the above section, for in the Final Report of the Minnesota Geological and Natural History Survey, Vol. II, p. XXII, Winchell says, speaking of the shales and shaly sandstones below the St. Lawrence which we now know as the Franconia, "They are underlain by a gray micaceous sandstone which is known recently as the *Dresbach sandstone,* from a town in Winona County where it is wrought for construction." A study of the fauna collected from the old quarries of No. 7 shows it to be identical with the "shales and shaly sandrock" of No. 8, and hence leads to the conclusion that No. 8 should also be included in the Dresbach formation, as the lithological change is accompanied by no faunal break. The conglomerate mentioned in No. 8 is wanting in other outcrops at that horizon, and hence is believed to be intraformational. Paleontological studies of the St. Croix Series in the Mississippi Valley give evidence of wide lithological variations within single formations. It is now generally recognized that changes in the type of sediment no greater than that from a sandy shale to a sandstone, are not reliable guides for the limitation of formations. Either a decided change in fauna or widespread evidence of physical break must be clearly recognized. No break that might be considered significant, either lithologically or paleontologically, has been observed in the beds above the river or in the quarries at Dresbach. This stratigraphic unit apparently extends below the level of the Mississippi.

Further description of the typical Dresbach is recorded in the same volume of the "Final Report of the Geological Survey of

Minnesota" in Winchell's discussion of the building stones of the state.[29] Quoting from this description:

> The sandrock quarried at Dresbach, Winona county (No. 32), is largely feldspathic, and rather soft, but it becomes harder on the drying out of the water which it contains in the quarry. It belongs to the St. Croix formation and very near its lowest part. The great anticlinal of that formation crosses Winona county bringing to view lower strata of the St. Croix than can be found along the Mississippi in any other county in that part of the state. These lowest beds cannot be found in the Mississippi bluffs further south, nor north. They probably might be opened in numerous places in the valley of the Root River and its tributaries, in Houston and Fillmore counties, in the direction of the anticlinal, which enters the state from Wisconsin. In the valley of Black River at Black River Falls, 33 miles from the Mississippi, east of Winona, the crystalline granites and schists appear, brought to the surface by this anticlinal.
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> The stone is evenly granular, gray, and of medium sized grain, very much resembling the Berea sandstone of Ohio. It is in beds that are quarried out from 6″ to 3′ thick. It is free from nodules of pyrite, or of coarse quartz pebbles. It can be sawed easily, and dressed with great facility with a hammer and chisel. Its strength in crushing pressure is 6,500 lbs. per sq. in. when placed on its bedding plane, and 3,750 lbs. when placed on edge. —Its durability under the weather is evinced by the projecting terrace-like shoulder which it causes along the base of the Mississippi bluffs. Its naturally gray color is found at a depth of a few feet from the weathered surface, the weathered and faded condition of the same strata being seen in the quarries at Dakota (No. 38) about a mile above Dresbach. It then becomes lighter, both in weight and color, absorbs moisture much more rapidly.——
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> The Dresbach quarry is owned by J. F. Tostevin, Jr., and was opened in 1881. It was the direct result of a visit by the state geologist . . . The stone . . . has been put into several buildings in St. Paul and Minneapolis and in the trimmings of Ladies Hall, one of the buildings at Carleton College.

Winchell has also described the microscopic character of the quarry rock at Dresbach.[30]

The Dresbach Formation. *Literature.* Subsequent descriptions of the Dresbach show apparently wide lithological and faunal differences. Berkey, in his account of that formation in the St. Croix Dalles region[31] divides the Dresbach into two distinct zones; the upper or "*Obolella polita*" zone, consisting of 20 feet of coarse greensand overlain by 10 feet of shaly sandstone, and the lower or "*Lingulepis pinnaeformis*" zone consisting of 50 feet of sandy, calcareous, argillaceous, and pyritiferous shales. Concerning the paleontology of this formation, Berkey says:[32]

[29]Winchell, N. H., ibid., pp. 178-179.

[30]Winchell, N. H., ibid., p. 179.

[31]Berkey, C. P., Geology of the St. Croix Dalles, American Geologist, Vol. XX, pp. 373-377, 1897; Vol. XXI, pp. 141-2, 273, 1898.

[32]Berkey, C. P., Geology of the St. Croix Dalles, Am. Geol., Vol. XXI, p. 273, 1898.

The Dresbach sandstones and shales are in great contrast to the Franconia sandstone. Whereas in the Franconia formation there are no shells and few casts; on the contrary, in the Dresbach shales immediately below they are so abundant that a single hand specimen from a favorable point contains hundreds of fragments of brachiopod shells. The range of species is limited and the considerable addition which is made in this paper as to variety of forms has not indicated a very extended geographic distribution. ——Fossils reported from the Dresbach at Taylors Falls and St. Croix Falls are:

Lingula ampla Owen
Lingula antiquata Hall
(*Lingulepis pinnaeformis* Owen) *Lingulepis acuminata* Conrad
Obolella polita Hall

In addition to these, the following were found recently by me:
Hyolithes primordialis Hall
Hypseloconus (*Metoptoma*) *recurvus* (Whitfield)
Agraulus convexus Whitfield
Ptychoparia calymenoides Whitfield

and a considerable number of new species which are described in a following chapter.

A part of the conglomerate that is locally developed at Taylors Falls, Minnesota, at the contact with the diabase is referred by Berkey to the Dresbach. From this conglomerate, and from the "Upper Dresbach" he described the following new species:[33]

Dresbach conglomerate

Tryblidium rectilaterale
Tryblidium convexum
Tryblidium extensum
Tryblidium corpentulum
Tryblidium aduncum
Hypseloconus recurvus var. *elongatus* (UD)
Scaevogyra minnesotensis
Euomphalus strongi var. *sinistrosus*

Upper Dresbach

Hypseloconus cornutiformis
Hypseloconus capuloides
Hypseloconus cylindricus
Hypseloconus stabilis
Agraulus hemisphericus
Cheilocephalus st. croixensis

This fauna was apparently a local development as Berkey suspected, for up to the present time no Cambrian locality in the Mississippi Valley has yielded a similar fauna, unless that recently found in the Ozark Mountains proves to be the same.

The St. Croix Series is exposed only in the extreme northeastern corner of Iowa, along the Mississippi River and its tributaries. There

[33]Berkey, C. P., ibid., pp. 275-292, Plates 19, 20, 21.

the Dresbach is known as the sandstone underlying the St. Lawrence (thickness of 50 feet according to Calvin).[34] It is described as a sandstone with bands of glauconite, and a thickness of 150 feet is assigned it by Calvin. The Iowa Geological Survey in 1913 gave as its lower limit the Hinckley Sandstone.[35] In Walter's "Trilobites of Iowa"[36] its lower limit is given as the Sioux Quartzite.

The Iowa geologists apparently have included the Franconia sandstone as well as possible lower formations under the name "Dresbach."[37] While Hall, [38] in his study "Geology and Underground Waters of Southern Minnesota," has included in the Dresbach formation only the massive sandstone between the lower beds of the St. Lawrence (which probably included a large part of the Franconia) and the shales such as appear in and below the quarries at Dresbach. He describes it as an "incoherent fine-grained sand of a prevailingly white color in its upper portion, followed downward by more compact layers with associated shaly beds." He gives the thickness of the Dresbach as 100 feet in Winona county, 60 feet in Houston county to the south, and 50 feet in Wabasha county to the north. However, he notes that "Beneath the Dresbach sandstone lies a series of beds having a persistently shaly habit.—Farther south these beds become less shaly and attain a thickness of several hundred feet, a large part of which consists of water-bearing sandstone."[39]

In Walcott's provisional classification of the Upper Cambrian (1914), he assigns a thickness of 100 feet to the Dresbach, and gives the following lithological characters:

"Massive-bedded, rather coarse-grained sandstone, with a thin bed of shale at the base and shaly sandstone near the middle. Fossils almost entirely of shells of *Dicellomus* and *Lingulella*."[40]

The area covered by Twenhofel and Thwaites in their study of the "Paleozoic Section of the Tomah and Sparta Quadrangles"[41] lies only 18 miles east of Dresbach, Minnesota. They note that "At Dresbach the character and sequence of the strata appear to be quite similar to what they are in these two quadrangles, although lower shaly strata are present there which have not been differentiated in

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[34]Calvin, Samuel, Notes on the Geologic Section of Iowa, Journal of Geology, Vol. 14, p. 572, 1906.

[35]Keyes, Charles, Iowa Geological Survey, Annual Report, Vol. 22, p. 155, 1912.

[36]Walter, O. T., Iowa Geol. Survey, Annual Report, Vol. 31, 1923-4.

[37]Calvin, Samuel, op. cit.; Walter, O. T., op. cit.

[38]Hall, C. W., United States Geological Survey, Water Supply Paper 256, p. 47, 1911.

[39]Hall, C. W., op. cit., p. 47.

[40]Walcott, C. D., Cambrian Geology and Paleontology II, Dikelocephalus and other Genera of the Dikelocephalinae. Smithsonian Misc. Collection, Vol. 57, p. 354, 1914.

[41]Twenhofel, W. H., and Thwaites, F. T., Journal of Geology, Vol. 27, pp. 615-617, 621-623, 1919.

this area." They suggest that some of the unexposed Cambrian strata included by them in the Dresbach may be Eau Claire and Mt. Simon. The Dresbach of the Sparta-Tomah area is characterized as a gray to yellow, poorly cemented quartz sandstone, with clean, well-rounded, well sorted grains, interlaminated with thin seams of green sandy shale. Cross-bedding and mudcracks are locally present, in a horizon about 100 feet below the base of the Franconia. "The strata are not continuous for long distances, and with the exception of worm-perforated beds, which are prominent in the upper horizon, it has not been found possible to identify any portion beyond the limits of a single exposure." The thickness of the exposed Dresbach in the Sparta and Tomah Quadrangles is given as about 300 feet, though "well records show that from 590 to 615 feet are present from the base of the Franconia formation to the pre-Cambrian floor." No fossils were observed except for worm tubes which are extremely abundant in the upper beds. These upper beds have more recently been assigned by Ulrich to the basal Franconia.[42] The sediments of the Dresbach formation were thought by Twenhofel and Thwaites to have accumulated in shallow water above wave-base or above water level.

Thwaites, 1923, again describes the Dresbach, in "Paleozoic Rocks found in Deep Wells in Wisconsin and Northern Illinois,"[43] this time separating it from the Eau Claire and the Mt. Simon formations. He says: "The Dresbach consists of medium-grained pure white sandstone with some yellow layers. The cement is mainly silica and varies greatly in amount; locally the formation is quartzitic. The upper and lower contacts are difficult to make out in well sections. The writer has excluded from the formation all fine-grained, calcareous or glauconitic sandstones. In central and northeastern Wisconsin the base cannot be determined, since the only change is in thickness of bedding. Not counting this district, the thickness varies from 40 feet at Union Grove, Wisconsin, to 180 feet at Chicago. In consequence of the high porosity and great purity of the formation it yields excellent water."

Thwaites separates the Dresbach sandstone from the underlying Eau Claire and Mt. Simon formations. The Eau Claire is said to be marked by extreme variability in character, scarcely any two well records showing the same succession in detail. A three part subdivision in which a fine-grained, calcareous sandstone separated by two members of gray and red calcareous shale and marl with some dolomitic beds, can usually be distinguished. Linguloid shells are locally prominent. The formation varies from 70 to 410 feet, averaging about 350 feet. The upper limit of the Mt. Simon is said

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[42]Ulrich, E. O., Notes on new names in table of formations and on physical evidence of breaks between Paleozoic Systems in Wisconsin. Trans. Wis. Acad. of Science, Arts, and Letters, Vol. XXI, p. 93, 1924.

[43]Thwaites, F. T., Journal of Geology, Vol. XXXI, pp. 550-554, 1923.

to be difficult to determine, owing to the variable character of the overlying Eau Claire.

Ulrich, (1924)[44] by very definitely delineating the base of the Franconia, has given an excellent guide to the recognition of the Dresbach-Franconia contact. He considers the initial bed of the Franconia formation to be a fossiliferous deposit of reworked Dresbach sand. In the southern part of the area, from La Crosse south, this bed is called the Ironton sandstone member of the Franconia formation. It is described as a 2 to 12 or 15 foot bed, composed of reworked, washed, and relatively coarse residual grains of Dresbach sandstone, the surface of which had previously been subjected to subaerial leaching and wear, and containing a few grains of glauconite and other material not present in the undisturbed underlying Dresbach. He says, however, "to make sure of the identification of the Ironton member it is advisable to search for its characteristic fossils. In the Dresbach proper no organic remains—except perhaps worm burrows—have been so far observed." The most abundant and characteristic fossils of the Ironton are the "nearly hemispheric cephalic shields of several species of a new genus of trilobites, one of which was long ago described by Whitfield under the name *Arionellus convexus*" (*Camaraspis convexus* Ulrich and Resser). In the northern part of the area, from Trempeleau, Wisconsin, northward, the fauna of the Ironton member has not been recognized. There the basal sandstone of the Franconia seems to be a coarse sandstone with more glauconite than is present in the Ironton member, and "a fauna consisting entirely of a few species of inarticulate brachiopods," a species of *Dicellomus* usually referred to *Dicellomus politus* being most abundant, though "a small elongate and very narrow species of *Lingulella* is more characteristic of this zone."

The Dresbach Formation. *Type Locality.* In and near Dresbach, a little village of Winona county, Minnesota, there are several good outcrops of the formation that bears its name. The Tostevin quarries, now long abandoned, are still accessible and form an excellent basis for study of the lower 40 feet of the formation exposed in that locality. They are in the south end of town, between the C., M. & St. P. Railroad and the Mississippi River. These lower beds are also well exposed a short distance south of the quarries, in the steep-sided ravine made by a small creek between its mouth at the river and the bridge on Minnesota State Highway No. 3. Continuing up from the bridge scarcely 500 feet, where the creek skirts the bluff, is a 22 foot escarpment of sandstone, the base of which is but slightly above the upper beds of the quarries. The strata immediately overlying these are exposed very poorly or not at all in and near Dresbach, and hence the next 30 feet admit of no detailed

[44]Ulrich, E. O., ibid., pp. 90-94.

description. This is most unfortunate, for the covered beds are so located stratigraphically as to cause some question as to just where the upper limit of the Dresbach should be drawn in this section. Above the largely covered interval is a road-cut made very recently (fall of 1927) which discloses 30 feet of sandstone that have previously been almost entirely covered. This road-cut is almost directly above the 22 foot escarpment. Whether or not the Dresbach-Franconia contact lies in the road-cut could not be determined with absolute certainty. It may be entirely Franconia. That it is all Dresbach is highly improbable. The road continuing from this outcrop to the top of the bluff discloses the strata at a number of places.

The complete section at Dresbach may be summarized thus:

Section II

Section at Dresbach, Minnesota, up the creek south of the quarries, thence up the road west of the village.

7. Soil and mantle rock ..... 6′

New Richmond sandstone:

6. Sandstone, coarse, well-cemented, brown to reddish... 22′

Oneota dolomite:

5. Limestone, gray to buff dolomitic; upper beds cherty and fossiliferous; lower beds aranaceous ..... 150′

Jordan sandstone:

4. Sandstone, massive white to yellowish, fine to coarse, partly crossbedded; poorly to well-cemented ..... 150′

St. Lawrence formation:

3. Dolomite, shaly and greensand, poorly exposed ..... 140′

Franconia sandstone:

2. Sandstone, massive, varicolored, generally fine-grained but coarser toward the base. Greensand and shales prominent at some horizons. Some beds with abundant *Dicellomus politus* ..... 100′

Dresbach formation:

1. Sandstone, massive, buff, gray, yellow, and white with shaly beds toward the base and top. Friable to fairly well-cemented. The lower half in which the Tostevin quarries are located has a number of highly fossiliferous beds; the upper half is sparingly fossiliferous ..... 100′

Level of the Mississippi River.

The lowest beds exposed at Dresbach may be seen at the mouth of the creek, just south of the quarries. The strata there consist of seven feet of gray sandy shale with an abundance of shells of *Dicellomus politus* in the sandy layers, and occasional mudcracks in

the blue, argillaceous layers that separate them. These shales are seen below the level of the Mississippi River. Immediately overlying them is a three-foot bed of massive gray sandstone. This bed is sparingly fossiliferous, a few specimens of *Hyolithes primordialis, Crepicephalus iowensis,* and *Anomocarella ? winona* having been found. Resting upon this massive bed of sandstone is twelve feet of gray sandy shales or shaly sandstone. Sandy beds, two to six inches in thickness, are interspersed among the shales, and several of them carry fossils. *Dicellomus politus, Lingulella ampla, Hyolithes primordialis, Crepicephalus iowensis, Anomocarella? winona, Lonchocephalus minor,* and *Dresbachia amata* were collected from these beds.

These are the same beds as the shaly sandstone exposed in the lower quarry a few rods distant.

Section III[45]

Section in the Lower Tostevin Quarry, Dresbach, Minnesota.
Top of the Quarry.

4.	Sandstone and shale interbedded; thin, irregular beds, up to 2 or 3 inches thick. Some of the more ferruginous sandy beds are very fossiliferous. Some with iron concretions	10′ 0″
3.	Sandstone, fine, massive, gray with buff mottling. Numerous traces of fossils, and an occasional brachiopod or trilobite cephalon	3′ 0″
2.	Sandstone, thin-bedded, buff, with many ferruginous brown streaks parallel to the bedding. Traces of fossils especially in the brown seams. A few very good specimens of *Hyolithes*, brachiopods, and trilobites	1′ 3″
1.	Covered	8′ 0″
	Level of the Mississippi River.	
	Total	22′ 3″

A large collection of fossils was made from bed four. The number of specimens in these beds is unlimited, as they are crowded so closely together that they interfere with each other, and many as a consequence are broken. Species identified from this horizon include *Agnostus josepha, Anomocarella? winona, Crepicephalus iowensis, Lonchocephalus minor, Pagodia thea?, Dicellomus politus, Lingulella ampla,* and *Hyolithes primordialis.*[46]

Outcrops of these sandy shales were observed at several other places in the vicinity of Dresbach. On the former State Highway No. 3, now abandoned, within one-half mile of the quarries to the south, most of these species were collected from the thin-bedded

[45]Ulrich considers this section to be Eau Claire—personal communication.
[46]"A typical upper Eau Claire fauna"—Ulrich, E. O.—personal communication.

buff sandstone that outcrops in the roadbed, 11 to 14 feet above the river level. At about the same horizon, 15 to 20 feet above the level of the Mississippi, in the extreme north part of Dresbach, the thin-bedded sandstone in a dry gulley contains myriads of the same forms. Here also are found small regular impressions of flat plates, most commonly hexagonal in outline, which are suggestive of cystoids. They are exceedingly plentiful in some thin layers.

The upper Tostevin quarry at Dresbach discloses the strata immediately overlying the lower quarry rock. The beds are massive, buff to white, weathering gray, with brown limonitic splotches marking almost obliterated fossils. The sandstone is very fine-grained and well sorted. A few thinner beds are very fossiliferous and brown and ferruginous. Even the massive beds often contain abundant brachiopod shells, among them, *Dicellomus politus, Lingulella acuminata,* and fragments of a linguloid species somewhat resembling *Lingulella phaon. Hyolithes primordialis* is fairly common, but the trilobite remains are as a rule poor and fragile, and limited to small specimens. *Lonchocephalus minor* is most usual, though *Crepicephalus iowensis* is present, as well as a small form that may be at least closely related to *Pagodia thea.* There is one especially fossiliferous bed that can be followed about half way around the quarry from the south. It lies just above a strongly ferruginous bed, and ranges in width from four inches to zero where it pinches out near the center of the quarry.

The rock is for the most part very even-bodied and soft, breaking easily into dimension blocks and soon case-hardens to a firm building stone. Traces of heavy cross-bedding in some of the massive beds of the upper quarry are discernible. This is the source of the building stone described by Winchell, and was the best-known part of the formation to which he gave the name *Dresbach.*

About two and one-half miles north of the quarries at Dresbach, is an exposure of the strata that is the equivalent of the Dresbach quarry rock. This section through the old quarry at Dakota is given below:

Section IV

Section one-half mile north of Dakota, Minnesota.

6.	Sandstone similar to that below, but thin-bedded and showing cross-bedding	3′ 0″
5.	Sandstone,[47] massive, buff to gray, weathering gray with brown streaks, marking ferruginous bedding planes. In these ferruginous layers fragments of trilobites and brachiopods are abundant, but are too poorly preserved for identification. *Hyolithes primordialis* is present. Indications of heavy cross-bedding	12′ 0″

[47]"Beach deposited sandstone at the base of the Dresbach as defined by me."—E. O. Ulrich—personal communication.

4.	Clay-shale, thin-bedded, irregular, greenish-gray, with conspicuous white mica	2′ 6″
3.	Sandstone, fine, gray, with abundant fossils, including *Crepicephalus iowensis, Lingulella acuminata, Dicellomus politus, Lingulella ampla, Hyolithes primordialis,* and *Anomocarella woosteri?* Some rounded spots of light sand suggest diagenetic action, possibly a conglomerate	8″
2.	Mostly covered. Some gray sandstone with many brachiopods and *Hyolithes primordialis,* interbedded with soft gray shales	2′ 8″
1.	Covered interval	20′ 8″
	Level of the Mississippi River.	
	Total	41′ 6″

The covered interval at the bottom of the last section is largely compensated for in the section at the Dakota stock yards. It follows:

Section V

Section at the stock yards and up the road to Minnesota State Highway No. 3, Dakota, Minnesota.

4.	Sandstone, massive, gray, fine-grained and even bedded. Somewhat fossiliferous, but preservation poor	23′ 6″
3.	Shale, sandy, gray, fossiliferous	5′ 0″
2.	Sandstone, gray, rather massive, in part fossiliferous. Considerable concentration of iron, and fossils largely obliterated	8′ 0″
1.	Mostly covered. Some sandy shale with abundant brachiopods, including *Lingulella ampla, Lingulella acuminata, Dicellomus politus,* with *Hyolithes primordialis* and occasionally *Crepicephalus iowensis*	10′ 0″
	Level of the Mississippi River.	
	Total	46′ 6″

It has been previously noted that the outcrops at Dresbach include a lower horizon in the St. Croix series than is known elsewhere along the Mississippi in Minnesota. Calculations based on a comparison of a number of complete sections along the river indicate that the strata dip northwest at an average of between 2 and 2½ feet per mile. The Dresbach is below the river level at Wabasha, less than 50 miles up the river from the village of Dresbach. Thus the outcrops in the vicinity of La Moile, about 10 miles up the river from Dresbach, are approximately 20 feet higher in the section than would be indicated by their position with reference to the level of the Mississippi River. The following sections are believed to include the horizon of the upper quarry at Dresbach:

Section VI

Section two miles south of La Moile, roadcut in Minnesota State Highway No. 3, and outcrop below the railroad tracks.

3.	Sandstone, coarse and yellow to medium and fine-grained, white; some thin-bedded and even-bedded; more is coarsely cross-bedded; most beds with abundant fragments of brachiopods	10′ 0″
	Top of cliffs below railroad tracks.	
2.	Sandstone, massive, white to gray with yellow and brown stains. Fairly cemented where fresh; weathers to loose sand. Traces of trilobites in concentrations of iron	19′ 0″
1.	Partly covered; some gray sandstone with fragments of brachiopods at the base	7′ 0″
	Level of the Mississippi River.	
	Total	26′ 0″

Section VII

Section in roadcut one mile south of La Moile, directly across the river from Trempeleau, Wisconsin.

4.	Sandstone, coarse to medium, yellow and brown, with some brachiopods. Poorly cemented. *Lonchocephalus* sp. present, but specimens crumbled	15′ 0″
3.	Sandstone, white and light brown, fine-grained, and mottled; very friable. The bed seems to be filled with tiny fragments of shell and yields occasional good fossil specimens. Those identified from this bed include *Hyolithes primordialis, Menomonia calymenoides, Millardia optata, Amphion, matutina, Lonchocephalus chippewaensis,* and *Pemphigaspis bullata*	3″
2.	Sandstone, fine-grained, yellow, white and brown, very friable; cross-bedded; traces of fossils	7′ 0″
1.	Covered interval	15′ 0″
	Level of the Mississippi River.	
	Total	37′ 3″

Bed 3, of the above section, it may be noted, carries a fauna that is typically Eau Claire, as defined by Ulrich. A fair number of fossils was found, but owing to the extremely friable nature of the sandstone, only a few specimens were transported successfully. Two complete dorsal shields of minute trilobites were collected from this bed. The prevailing dip of the strata should bring the equivalent of this bed somewhere within the upper 10 feet of the Upper quarry (Tostevin's) at Dresbach.

Above the quarry rock at Dresbach, where the creek south of the quarries has cut along the edge of the bluff, is a twenty-two foot escarpment of massive cross-bedded sandstone. It is fine to medium-grained, friable, and predominantly white. Some beds are yellow to brown, and there is some local concentration of iron along the bedding planes. Occasional horizons carry *Dicellomus politus*, and less frequently *Hyolithes primordialis* may be found. There is little reason to think that these beds were originally less fossiliferous than those below. It seems more probable that thorough leaching has largely removed traces of organisms.

The strata that overlie this friable sandstone are not satisfactorily exposed at Dresbach, and the characteristics of the next thirty feet of sediments had to be sought elsewhere. The nearest really good outcrop of these beds is along Minnesota State Highway No. 3 at a point four miles north of Dakota, or six miles from the quarries at Dresbach, where the following section was measured:

Section VIII

Section four miles north of Dakota, Minnesota, on Minnesota State Highway No. 3.

7.	Sandstone, brown to yellow; coarse, somewhat cross-bedded with abundant brachiopods	12′ 0″
6.	Covered interval	41′ 4″
5.	Sandstone, brown, fine-grained, sugary	2′ 0″
4.	Sandstone, massive, coarse to fine, white to brown, cross-bedded; locally abundant traces of brachiopods	30′ 0″
3.	Covered interval	10′ 0″
2.	Sandstone, gray, fine-grained, fairly well cemented; massive, weathering even-bedded. Abundant traces of fossils, but few are well preserved. The best specimens are in the lower five feet. *Hyolithes primordialis, Agnostus josepha, Lonchocephalus minor,* and *Crepicephalus iowensis* have been identified from this bed	25′ 0″
1.	Covered interval	30′ 0″
	Level of the Mississippi River.	
	Level	150′ 4″

Owing to the regional dip, this section is about 10 feet higher than that at Dresbach, and Bed 2 is at the horizon of the sandstone escarpment along the creek and above the upper quarries at Dresbach. Bed 4 is exceedingly variable, and may include the Dresbach-Franconia contact, though it was not definitely recognized. However, it is possible that the contact may lie within the covered interval above. Bed 7 is certainly Franconia.

Just south of La Moile is another outcrop at the horizon above that of the upper quarries at Dresbach. Its character is shown in the following section:

Section IX

Section along Minnesota State Highway No. 3, first outcrop south of La Moile, Minnesota.

4.	Sandstone, coarse to medium-grained, brown to yellow	10′ 0″
3.	Sandstone, fine-grained, white, with considerable cross-bedding and color-banding. A few brachiopods and fragments of trilobites	10′ 0″
2.	Sandstone, coarse, massive, cross-bedded and yellow	8′ 4″
1.	Covered interval	25′ 0″
	Level of the Mississippi River.	
	Total	53′ 4″

The lateral variation within short distances is well brought out in sections VIII and IX, which are about four miles apart. The regional dip brings the strata in section IX about eight feet higher in the geologic section of the Dresbach, than section VIII. Keeping this in mind, a comparison of the two sections shows that the coarse, yellow sandstone of bed 2, section IX is at the horizon of the gray, fine-grained sandstone that yielded the fossils in bed 2, section VIII.

Since the field work for this study was completed, a number of road-cuts have been made in changing the route of Minnesota State Highway No. 3, between LaCrosse, Wisconsin, and Winona, Minnesota, particularly in the portion between La Moile and Winona, that are at such an elevation that they doubtless include much of the Dresbach formation. A study of these new exposures may give much additional data concerning the extent of lateral changes in these strata.

The lower limit of the Dresbach formation along the Mississippi is, in all cases, below the level of the river; the upper limit, that is the contact with the Franconia sandstone, is frequently difficult to locate. This is particularly true in the region around the type locality, for the contact is usually in the turfed-slope of the bluffs. Even where it may be exposed at the surface, the nature of the contact is such that it is exceedingly difficult to recognize. The Ironton sandstone member, which marks the lower limit of the Franconia and can usually be recognized fairly easily, does not extend as far northwest as Dresbach, at least not with its usual lithological and paleontological characteristics; while the fossiliferous bed of reworked Dresbach sands that forms the initial deposit of the Franconia to the north is not well defined.

The following detailed section measured through the Tostevin quarries and up the bluff road at Dresbach includes the lower beds of the Franconia. The contact as indicated, however, is open to discussion. It was disclosed (fall of 1927) by a roadcut made in widening the road up the bluff west of the village.

Section X

Section through the Tostevin quarries and up the bluff road, west, Dresbach, Minnesota.

Top of the road-cut.

15.	Sandstone as in beds below, but with numerous blue clay seams between inch beds of coarse sandstone	1′ 6″
14.	Sandstone, alternating white and brown, streaked, massive, very friable; medium to coarse grained. One foot above its base is a 3″ layer in which the matrix is soft, blue clay, and the grains of sand are very coarse. (This bed is quite similar to those containing fossils in the so-called Ironton member or base of the Franconia)	5′ 10″
13.	Conglomerate, pebbles of blue shale in a medium-grained sandstone matrix	8″
12.	Sandstone conglomerate. Pebbles up to 2″ in length, mostly flat, of fine brown sandstone in a matrix of slightly coarser gray to buff sandstone. This is probably the base of the Franconia	8″
11.	Sandstone, fine, white and brown. The brown is better cemented and seems to contain considerable argillaceous material. Some cross-bedding	1′ 0″
10.	Sandstone, massive bed, very fine, white	1′ 6″
9.	Sandstone, fine, buff, in a persistent horizontal bed, with rare specimens of *Hyolithes primordialis*, and *Hyolithes* sp. (a smaller more curved form) and a minute trilobite	2″ to 4″
8.	Sandstone, gray, thin-bedded, bedding slightly irregular, with a few thin partings of brown argellite. Beds slightly better cemented than those underlying them, perhaps due to admixture of small amounts of clay	2′ 8″
7.	Sandstone, massive, very white, very fine, friable; a few horizons less well sorted, with medium to coarse grains. Some thin beds are brown. Bright yellow color-banding brings out some cross-bedding	17′ 6″
6.	Sandstone similar to the beds, partly covered	31′ 0″
5.	Sandstone, massive, cross-bedded, fine to medium, friable, white mainly, though some beds are yellow to brown. Local concentrations of iron along bedding planes. Occasional horizons with *Dicellomus politus* and rarely *Hyolithes primordialis*	22′ 4″

4.	Sandstone, massive, white to gray, fine. Traces of fossils. Mostly very small forms are abundant and some are sufficiently well preserved for identification. They include *Dicellomus politus, Lingulella phaon*(?), *Hyolithes primordialis, Pagodia thea* (?), and *Lonchocephalus minor*	19′ 6″
3.	Shales, gray, sandy; several of the more sandy beds (2-6″) carry *Dicellomus politus, Lingulella ampla, Crepicephalus iowensis, Anomocarella? winona, Lonchocephalus minor, Hyolithes primordialis,* and *Dresbachia amata*	12′ 0″
2.	Sandstone, massive bed, gray, sparingly fossiliferous	3′ 0″
1.	Shale, gray, sandy. *Dicellomus politus* abundant. Mud-cracks	7′ 0″
	Level of the Mississippi River.	
	Total	126′ 6″

The Dresbach-Franconia Contact. Whether or not the eight inch bed of sandstone conglomerate in Section X is the initial bed of the Franconia is open to question. Such a conglomerate has not been observed elsewhere in the vicinity of Dresbach, but that does not preclude the possibility of its presence, for few apparent Dresbach-Franconia contacts are exposed. Intraformational conglomerates are rather characteristic of the St. Croix sandstones of the upper Mississippi Valley, and it is possible that this may be another such local development. A conglomerate similar in many respects is present in the lower Franconia beds at several places in Minnesota. It is found in an excellent section of the St. Croix sandstones exposed in a dry gully two miles north of Reeds Landing; and several such conglomerates have been noted in the same formation in the bluff three miles north of Stillwater, as well as at Marine-on-the-St. Croix. There are some reasons, however, for suspecting that this conglomerate is not intraformational. It may be noted that there is a decided change in the size of grain above and below the conglomerates. The beds below are massive, friable, and fine-grained, and in every respect like the unquestioned Dresbach lower in the section, except for the presence of small amounts of clay. The beds above the conglomerates have still more clay; and in addition, they are very much coarser grained than those below. They are also devoid of fossils; while those below have occasional fossils principally of the *Hyolithes* type so characteristic of the Dresbach. If this conglomerate marks the Dresbach-Franconia contact, 117 feet of Dresbach sandstone is present above river level in this type section. Or perhaps as Dr. Ulrich suggests,[48] the Dresbach-Franconia contact may lie between beds 7 and 8 of Section X. Bed 8 may be reworked material derived from bed 7, and distinguished from it by the presence of

[48]Ulrich, E. O., personal communication.

small amounts of clay. Clay has not been observed in the upper horizons of the undoubted Dresbach. If this be the true contact, the Dresbach present above the river level in the type section has a thickness of slightly over 111 feet.

One mile north of this section there is an outcrop of undoubted lower Franconia sandstone at an elevation of 127 feet above the river level. Fine sands alternate with coarse, and the massive beds are separated by occasional seams of blue shale. There are several horizons of abundant brachiopod shells and some greensand. The only lower outcrop on the bluff is a six foot bed of sandstone that is separated from the sandstones above by thirty feet of turfed slope. In this lower sandstone, conspicuous large grains are present in a matrix of smaller sand grains, and some beds have a considerable admixture of clay. These beds are for the most part unfossiliferous, though they contain a few impressions of brachiopods. This outcrop may represent a coarser phase of the upper beds of the Dresbach. It is the type of deposit from which the coarse grains may have been concentrated to make the initial deposit of the Franconia, as described by Ulrich.[49]

One of the sections analyzed by Graham in a recent "Petrographic Study of the Cambrian Sandstones of Minnesota and Wisconsin"[50] is the type section at Dresbach. He gives detailed mechanical analyses of the Dresbach and Franconia formations from that section that show a number of interesting things about these sediments. The Dresbach sandstone is characterized by extreme uniformity in its size grade distribution. Only one sample from this section could be called anything but a very fine grained sandstone, and that was fine to medium grained. There is some increase in coarseness toward the top of the section. Heavy minerals present in the Dresbach include garnet, zircon, tourmaline, rutile, and staurolite. The amounts of those present do not differ, in any striking way, from the heavy mineral content of other formations of the St. Croix series, nor is their size distribution significant.

The development of coarse sandstone near the base of the Franconia is widespread and much more clearly discernible than is any phase in the upper Dresbach. In fact the variation in the upper strata of the Dresbach is so great that no reliable generalizations can be made regarding its character. Doubtless there was a slight break in sedimentation between the deposition of the Dresbach and Franconia formations, as described by Ulrich,[51] and suggested by field and paleontological relations. However, the exact location of such a break between an eroded sand and the reworked sand derived from the underlying formation is difficult to distinguish on physical

[49]Ulrich, E. O., Trans. of the Wis. Acad. of Sci., Arts, and Letters, Vol. XXI, p. 93, 1924.

[50]Graham, W. A. P., op. cit., pp. 51-53, 76-77, 86-89.

[51]Ulrich, E. O., ibid., p. 93.

evidence alone. This is particularly true in formations in which there is very little difference in the mineral content, as in the Dresbach and Franconia. Ulrich states that there is usually a little admixed glauconite in the initial Franconia deposit that is not present in the Dresbach. However, the fact remains that these formations can usually be separated with certainty only on paleontological evidence. The Dresbach does carry fossils other than worm borings, even in its upper beds; but they are not present in any clearly defined zone, and are rare in most localities; while the basal beds of the Franconia are frequently fossiliferous and carry a limited and easily recognizable fauna. In view of this, it seems advisable to try to locate, particularly on paleontological evidence, the basal Franconia beds, in any attempt to determine the upper limit of the Dresbach.

The Dresbach in Wisconsin. Attention has already been called to the general southwesterly pitch of the gentle anticlinal fold that brings the Dresbach to the surface along the Mississippi River in southern Minnesota. It has been further pointed out that beds of the St. Croix Series which are below the river level at Dresbach come to the surface to the north and east in Wisconsin.

The Eau Claire sandstone and shales, according to the Wisconsin Geological Survey classification, immediately underlie the Dresbach sandstone. Fossils from it have been described and reported from a large number of localities within the area covered in this study. Eau Claire, Menomonie, St. Croix Falls, and Hudson, all in Wisconsin, are said to have outcrops of the Eau Claire formation; and it was hoped that by visiting these places possibly the Dresbach-Eau Claire contact could be determined, and the lower beds of the Dresbach, which are below the surface at the type locality, might be studied.

At the power dam on the Willow River, four miles east of Hudson, the lower 67 feet of sandstone and shales are completely exposed. This section starts below the foot of the dam. The type specimen of *Crepicephalus unca* Walcott came from the Eau Claire formation[52] of this locality where it is associated with *Millardia optata* (Hall). A section measured at the above outcrop is given below.

Section XI

Section on the north bank of the Willow River, below the power dam, four miles east of Hudson, Wisconsin.

Top of gorge.

9.	Glacial drift	72′ 0″
8.	Sandstone, thin-bedded and friable, yellow, with traces of fossils	4′ 0″

[52]Walcott, C. D., Cambrian Trilobites, Smithsonian Misc. Coll., Vol. 64, No. 3, p. 217 and Plate 35, figure 1 and 1a-e, 1916.

7.	Sandstone, yellow, fine-grained, thin-bedded to massive, with abundant specimens of *Anomocarella?* sp.	15′ 0″
6.	Sandstone, buff, hard and shaly, some blue clay partings up to 2″ in thickness; *Anomocarella?* sp. and *Lingulella acuminata* present	8′ 0″
5.	Sandstone, yellow, massive, with numerous trilobites, including *Lonchocephalus chippewaensis, Millardia optata,* and *Crepicephalus unca;* also shells of *Dicellomus politus*	12′ 0″
4.	Sandstone, thin-bedded and shaly	2′ 0″
3.	Sandstone, massive, gray with a profusion of brachiopods, particularly *Dicellomus politus. Crepicephalus iowensis* is also present in this bed	8′ 0″
2.	Sandstone, thin-bedded, and shale with myriads of brachiopods, including *Lingulella ampla* and *Dicellomus politus*	15′ 0″
1.	Sandstone, gray, massive, with occasional specimens of two trilobites that may both belong to the genus *Crepicephalus*	3′ 0″
	Level of the Willow River below the dam.	
	Total	139′ 0″

In the foregoing section there is no evidence of a break of any sort, and it is believed that only one formation is represented in the outcrop.

Wooster's section of the St. Croix sandstone at Hudson[53] shows no fossils in the lower 63 feet, and includes a bed (1) that yields species of *Conaspis, Wilburnia,* and other typical Franconia trilobites at an elevation of 95 feet above the lowest outcrop. There is no notable similarity between the succession of strata in the outcrop at the Willow River dam, and in the lower beds at Hudson, only four miles away. From their position, however, there is every reason to think that the beds that are lower than 60 feet above the base of the Hudson section are the stratigraphic equivalents of the outcrop of the Willow River dam.[54] As the Franconia trilobite bearing beds of the horizon mentioned above are not known to be at the base of that formation in any locality, and as strongly glauconitic beds are not characteristic of either the Dresbach or the Eau Claire formations, it seems logical to place the base of the Franconia below the greensands that underlie the trilobite-bearing beds (1. of Wooster's section). This, however, brings the base of the Franconia to a point only a little over 60 feet above the base of the Hudson section From this it is inferred that if the "Eau Claire" beds of Willow

[53]Wooster, L. C., Geology of the Lower St. Croix District, Geol. of Wis., Vol. IV, pp. 113-114, 1873-1879.

[54]Walcott evidently made this correlation, for he gives the Eau Claire formation, near Hudson, Wisconsin, as a locality in which several trilobites are found. He has described these in Smithsonian Misc. Collections, Vol. 64, No. 3, 1916.

River dam are present at Hudson, the Dresbach is wanting, and the Franconia formation rests directly on the "Eau Claire." However, a comparison of Section XI on Willow River with Section VII south of La Moile, which is undoubtedly Dresbach sandstone, shows that each has a horizon that yields *Millardia optata* and *Lonchocephalus chippewaensis,* associated with a number of other forms; while the lower beds at Hudson are said to yield *Dresbachia amata* and *Hyolithes primordialis,* which are also present in the quarries at Dresbach (Section X). In view of this, it seems more likely that the outcrop at the Willow River dam and the lower 50 to 60 feet at Hudson are really the equivalents of the Minnesota Dresbach.

A somewhat similar situation is met in the section at Cedar Falls, Wisconsin, six miles north of Menomonie.

A section measured along the Red Cedar River in the old quarries near the rapids below the power dam, and in the river banks below and above the dam, shows the presence of but two formations, the Franconia and an underlying sandstone that from its elevation correlates with the "Eau Claire" at Menomonie. The section follows:

Section XII

Power dam—Red Cedar River

17.	Sandstone, fine-grained, brown, with characteristic Franconia trilobites in occasional small exposures. Mostly covered from the escarpment above the dam to the top of the bluff	
	Top of the outcrop above the dam.	
16.	Sandstone, brown to white, medium to coarse, poorly sorted. Some beds carry abundant brachiopods. The Dresbach-Franconia contact is probably in these sands	25′ 0″
15.	Covered interval	5′ 0″
14.	Sandstone, medium-grained, gray, appearing massive where fresh but slabby where weathered. Well cemented to friable. Some beds have abundant brachiopods and *Hyolithes,* while others are devoid of fossils	17′ 0″
13.	Shaly sandstone and sandy shale, gray, irregular bedded, fucoidal, with many suncracks. Red iron oxides are present in the more shaly partings. Abundant brachiopods and some *Hyolithes* in the more sandy beds. Some fine cross-bedding	7′ 6″
12.	Sandstone, buff, hard, with brown and blue shales. *Dicellomus politus* and *Lingulella phaon* present with some fragments of trilobites and *Anomocarella? winona* and *Pagodia thea*	5′ 0″
11.	Sandstone, massive, gray, with blue shale near the middle. Abundant *Hyolithes* and some brachiopods	5′ 6″

10.	Sandstone, soft, thin-bedded, with abundant brachiopods in some beds	1′ 8″
9.	Sandstone, massive, with iron concentration	2′ 6″
8.	Shale, fissile, blue	3″
7.	Sandstone, buff to gray, fine-grained with a few excellent specimens of *Lingulella phaon* at the top	2′ 6″
6.	Sandstone, fine, cross-bedded, brown to yellow	1′ 3″
5.	Sandstone, buff and brown, mottled. Almost devoid of fossils	6′ 6″
4.	Sandstone, buff and brown mottled, with *Lonchocephalus chippewaensis* and *Dresbachia amata*	8″
3.	Sandstone, coarse, buff and brown, cross-bedded, concretionary	1′ 0″
2.	Sandstone, medium-grained, buff, cross-bedded with occasional *Dicellomus politus*	1′ 0″
1.	Sandstone, massive, fine-grained, buff, with a few brachiopods	2′ 0″
	Level of the Red Cedar River at low water.	
	Total	84′ 4″

At Menomonie, six miles down stream, the lowest beds exposed, as given in Wooster's section[55] along the Red Cedar River and Wilson Creek, yield *Dicellomus politus, Lingulella* cf. *acuminata, Crepicephalus iowensis, Lonchocephalus minor,* and *Hyolithes primordialis.* In addition, Walcott has figured *Menomonia calymeniodes* from the "Eau Claire" near Menomonie.[56] These beds must be only a few feet below the lowest strata exposed at Cedar Falls. There seems to be no lithological or paleontological break in the beds below No. 16 in the Cedar Falls section. It is therefore concluded that the beds below the Franconia both at Menomonie and at Cedar Falls are the stratigraphic equivalents of the Dresbach of Minnesota.

The Franconia sandstone, as limited by Ulrich, clearly makes the Upper Dresbach of Berkey (exposed in the St. Croix Dalles region) the basal beds of the younger formation. The fauna of the "*Obolella polita*" zone thus becomes that of the basal Franconia. It is rather surprising to find several trilobites of the *Camaraspis* type in these beds in the vicinity of Franconia and St. Croix Falls, when they are known elsewhere only from the Ironton member of the Franconia in the southern part of Wisconsin and Minnesota.

The strata immediately below the "*Obolella polita*" beds are the sandy shales at St. Croix Falls and the conglomerate and calcareous

[55] Wooster, L. C., ibid. p. 115.

[56] Walcott, C. D., Smithsonian Misc. Collections, Vol. 64, No. 3, Plate 26, figure 4, 1916.

shales at Taylors Falls, which were termed by Berkey the "*Lingulepis pinnaeformis*" beds. The shales at St. Croix Falls are quite similar lithologically to those at Eau Caire on Mt. Washington and also to the shales in the lower quarry at Dresbach. Fossils reported from this horizon at St. Croix Falls include *Menomonia calymenoides* (Whitfield), *Hyolithes primordialis* Hall and *Lonchocephalus chippewaensis* (Owen) and these beds have been referred by Walcott to the Eau Claire formation.[57] However, they are stratigraphically just below the lower beds of the Franconia as now defined, and the fossils described from there have been found in the Dresbach formation near the type locality. (See Section VII.) It therefore appears that Berkey was correct in correlating the sandy shales at St. Croix Falls with the Dresbach.

The general southwest dip of the Paleozoic formation brings older formations and lower parts of the Cambrian section to the surface in the northeast direction in Wisconsin. Forty miles east of Hudson, at Menomonie, however, the lowest outcrops still correlate with the Dresbach. At Rock Falls, which is southeast of Menomonie, southwest of Eau Claire, and close to half way between them in an east-west line, there is an excellent exposure of the "Eau Claire" in the ravine at the foot of the falls. At the time that Wooster described the Cambrian strata of this region only twenty feet of the sandstones and shales were disclosed. These he believed to lie stratigraphically between the lowest outcrop at Menomonie and the highest at Eau Claire.[58] At the present time there is a fifty foot outcrop at Rock Falls. The section is composed chiefly of massive gray sandstone with some interbedded gray shales. A three foot shaly horizon at the bottom of the section is literally filled with fossils, *Dicellomus politus, Dicellomus pectinoides,* and *Anomocarella woosteri* being almost the only species represented. Further up in the section a greater variety is encountered. Walcott figures a single block of sandstone from this locality[59] which shows a number of species said to be characteristic of the Eau Claire formation. They include *Hyolithes primordialis* Hall, *Anomocarella onusta* (Whitfield), *Pagodia thea* Walcott, *Lonchocephalus chippewaensis* Owen, *Menomonia calymenoides* (Whitfield), *Crepicephalus iowensis* (Owen), *Dicellomus politus* Hall, and *Obolus matinalis* Hall. With the exception of *Anomocarella onusta* and *Anomocarella woosteri,* every one of these forms has been found in beds that correlate with the Dresbach. The upper beds of these strata are doubtless in part contemporaneous with the lower beds at Menomonie that carry a similar fauna, though they probably include a large part that is below the surface at that place. The presence of *Anomocarella woosteri* suggests correlation with the sandstone in the quarries at

[57]Walcott, C. D., ibid., p. 250, plate 34, 1916.
[58]Wooster, L. C., op. cit., p. 116.
[59]Walcott, ibid., plate 37.

Mt. Washington, Eau Claire, and also at Colfax, Wisconsin, as that trilobite is very abundant in limited beds at both places. Still no break in the section has appeared, and the entire exposure is apparently Dresbach.

The highest sedimentary rocks exposed in the vicinity of Eau Claire, Wisconsin, are those for which the Eau Claire formation was named. They are in the main highly fossiliferous, and consist of thinbedded and massive sandstones, and sandy shales. One of the best sections in these strata is on Mt. Washington, where the upper beds are well exposed in the quarries. The section follows:

Section XIII

Section on Mt. Washington, Eau Claire, Wisconsin.

	Top of Mt. Washington.	
8.	Mantle rock	2′ 0″
7.	Sandstone, massive, gray to buff, medium to fine-grained with some thin-bedded and shaly horizons. The bedding is wavy but there is little cross-bedding. The fauna includes *Crepicephalus iowensis, Saratogia volux, Lonchocephalus chippewaensis, Dresbachia amata, Pagodia thea, Anomocarella onusta, Dicellomus politus,* and *Hyolithes primordialis.* These are the beds of the upper quarry. Fine-grained	31′ 0″
6.	Sandstone, fine-grained, heavy-bedded, buff with abundant trilobites, brachiopods, and *Hyolithes,* including all species of the upper quarry and in addition, *Menomonia calymenoides* and *Anomocarella woosteri*	2′ 0″
5.	Sandstone, thin-bedded, fine, buff, with shaly partings, especially toward the top. Even-bedded with ripplemarks, suncracks, and fucoids	11′ 6″
	Entrance to lower quarry.	
4.	Mostly covered. Some shaly sandstone	15′ 0″
3.	Shale, sandy—really a very thin-bedded, well-cemented sandstone with blue shaly partings. Occasional traces of fossils. Fucoids, mudcracks, and ripplemarks	11′ 0″
2.	Covered interval	86′ 10″
1.	Sandstone, coarse to medium-grained, heavily cross-bedded. This is Mt. Simon sandstone	15′ 0″
	Level of the road at outcrop on school grounds.	
	Total	174′ 4″

Petrographic analyses of the Eau Claire formation at Mount Washington are said to be strikingly similar to those of the Dresbach in Minnesota, in the high degree of sorting and sizes of the constituent grains.[60] Although such generalized similarities cannot safely be made the bases for correlation, they are at least suggestive. Coupled with other evidence, they should bear some weight. The

[60]Graham, W. A. P., op. cit., p. 68.

fauna of the Mt. Washington section is strikingly similar to that of the Dresbach in Minnesota. In fact seven of the ten species of trilobites collected at Mt. Washington have been found in the undoubted Dresbach in Minnesota.

Fossils reported from the type localities may be compared thus:[61]

Dresbach formation at Dresbach, Minnesota.	Eau Claire formation at Mt. Washington
Amphion? matutina Hall	
Anomocarella? winona (Hall)	
	********
	Anomocarella onusta (Whitfield)
	Anomocarella woosteri (Whitfield)
Agnostus josepha Hall	*Agnostus josepha* Hall
Crepicephalus iowensis (Owen)	*Crepicephalus iowensis* (Owen)
	Crepicephalus texanus danance Walcott
Dresbachia amata Walcott	*Dresbachia amata* Walcott
Lonchocephalus chippewaensis Owen	*Lonchocephalus chippewaensis* Owen
Lonchocephalus minor (Shumard)	********
Menomonia calymenoides (Whitfield)	*Menomonia calymenoides* (Whitfield)
Millardia optata (Hall)	*Millardia optata* (Hall)
Pagodia thea?	*Pagodia thea* (Walcott)
	Saratogia volux Walcott
Hyolithes primordialis Hall	*Hyolithes primordialis* Hall
Dicellomus politus (Hall)	*Dicellomus politus* (Hall)
	Dicellomus pectenoides (Whitfield)
Lingulella ampla Owen	********
Lingulella cf. *acuminata* (Conrad)	*Lingulella* cf. *acuminata* (Conrad)
********	*Lingulella mosia* (Hall)
********?	*Lingulella phaon* (Walcott)
********	*Obolus matinalis* (Hall)
Cystoid ? plates	
Stenotheca sp. undt.	*Stenotheca* sp. undt.
Hyolithes sp. undt.	

From the general inclination of the strata, the beds at Eau Claire should be slightly lower in the Cambrian section than those outcropping at Dresbach. It is therefore not surprising that a few forms should be found at one locality that are not found at the other. So far as is known, *Anomocarella woosteri, Anomocarella onusta, Saratogia volux* and *Dicellomus pectenoides* are confined to the lower fossiliferous horizons.[62] They are present in the quarries at Mt. Washington, those at Colfax, Wisconsin, and in the lowest horizons at Rock Falls. *Amphion? matutina,* and *Pemphigaspis bullata* Hall,

[61]Species found at Dresbach and described from the Eau Claire formation at localities other than Eau Claire, and species found at Eau Claire, and described from the Dresbach formation at localities other than Dresbach are indicated by asterisks. (********)

[62]*Cedaria woosteri* (Whitfield) represents a totally distinct zone in the Eau Claire. It occurs only in Wisconsin and Alabama, whereas the upper Eau Claire fauna that is found in the Dresbach of Minnesota is widespread in the Rockies and Appalachians. C. E. Resser—Personal communication.

which are associated in Section VII, 10 miles from Dresbach, are apparently confined to the upper horizons, as is *Hyolithes* sp. undt., while *Anomocarella? winona* and *Lonchocephalus minor* are very rarely found elsewhere. Cystoid? plates are not definitely known from the lower horizons. *Lonchocephalus chippewaensis* and *Pagodia thea* are rare in the upper horizons. Species known only from one locality include *Lonchocephalus sospita* Walcott, *Crepicephalus texanus danance, Crepicephalus texanus elongatus* Walcott, and several brachiopods, as well as a few specifically unidentified trilobites, and the gastropods described by Berkey from his "*Lingulepis pinnaeformis* zone" in the St. Croix Dalles area. *Crepicephalus unca* is known only from what may be termed a middle horizon between those of the quarries at Dresbach, and at Mt. Washington. It has been found only at Willow River dam and near Hudson.

The lower beds at Dresbach have been correlated with the Eau Claire formation by Walcott.[63] A study of the type section at Dresbach shows that their fauna, though specimens are not present in such abundance, does extend up through the quarries representing Winchell's typical Dresbach. Collections from other sections in Minnesota give evidence confirming the logical inference, namely, that but one formation outcrops below the Franconia along the Mississippi River in Minnesota, and that formation is the Dresbach.

The fauna found at Dresbach is present in the "Eau Claire" beds of Wisconsin wherever fossils have been found in them, between the Mississippi and St. Croix Rivers and Eau Claire, Wisconsin. In the northeastern section at a lower horizon, which does not outcrop in Minnesota, there are a few forms, particularly *Cedaria,* of limited vertical range, which are, of course, not present in the vicinity of the type locality of the Dresbach. However, the bulk (over 70%) of the fauna of Mt. Washington has been found at or near Dresbach. In the presence of decided similarities, both in lithology and in paleontology, between the Dresbach of Minnesota and the Eau Claire of Wisconsin, it seems reasonable to believe that these two formations are in reality identical. It follows, therefore, that one name for the formations is sufficient, and that preference should be given to Dresbach because of its priority.

Lower Limitation of the Dresbach. Assuming that the Dresbach of Minnesota and the Eau Claire of Wisconsin are but one stratigraphic unit, it follows that the lower limit of the Dresbach formation must be that of the Eau Claire. The Mt. Simon sandstone is the formation immediately underlying the Eau Claire formation according to the classification now in use by the Geologic Survey of Wisconsin. Its type outcrop is on Mt. Simon at Eau Claire. There it is a series of unfossiliferous, coarse-grained or poorly sorted sand-

[63]Walcott, C. D., ibid., pp. 163, 165, 167, 192, 193, 200, 219.

stones in most places heavily crossbedded and containing considerable concentrations of iron along bedding planes and in concretions. It is as a rule very poorly cemented. Other outcrops that are believed to be Mt. Simon were observed along the Black River at various places down-stream from Black River Falls. At this locality as well as on Mt. Simon, large outcrops of the lower bluffs are separated from sandstone escarpments at or near their summits by a slope covered with vegetation for approximately 100 feet. The rock forming the outcrop at the top of Mt. Simon is a sandstone in which massive beds alternate with shaly phases. The sands are in the main not well sorted, although a few very small sorted beds may be found. Fine-grained sands alternate with coarse and they range in color from white to pinkish, greenish, and yellow. Ironstone concretions and concentrations of iron along bedding planes are common, as is crossbedding. The upper five feet have several beds containing myriads of broken shells of small brachiopods. *Lingulella acuminata* was identified from these beds. It is believed that these fossiliferous beds are at least very close to the lower limit of the Dresbach (Eau Claire of Wisconsin). However, no unconformity was distinguished. The outcrops high in the bluffs along the Black River were of the same nature.

Aside from these localities, the Dresbach-Mt. Simon contacts are known only from well records. Thwaites[64] says that the upper limit of the Mt. Simon sandstone is difficult to determine because of the variable nature of the overlying formation. No physical evidence of a break at the base of the Dresbach is known. The finer grain, the presence of shales, and of the remains of organisms serve to distinguish the Dresbach from the coarse, massive, unfossiliferous sandstone of the Mt. Simon. The Mt. Simon sandstone has not been recognized as a separate formation in Minnesota, unless it be the equivalent of the Hinckley sandstone. In Minnesota the lower limit of the blue shales that characterize the lower Dresbach probably marks its contact with the underlying Hinckley sandstone.

Summary

The type outcrop of the Dresbach formation is found in the abandoned Tostevin quarries at Dresbach, Winona county, Minnesota. A study of the section through the quarries shows that the underlying and overlying clastics that occur there below the base of the Franconia are included within this one stratigraphic unit. In the type locality, the Dresbach is a marine deposit with accumulation chiefly below wave base as is evidenced by the preservation of the fauna. At times parts of the formation must have been above water, for suncracks are preserved at several localities, and shallow water deposition is inferred from the presence of ripplemarks.

Lithologically, the formation consists of well sorted white, buff,

[64] Thwaites, F. T., op. cit., p. 554.

or gray, finegrained sandstone. There is some increase in coarseness of grain toward the top of the formation, and usually sandy shales occur toward the bottom. The upper horizons are, as a rule, of massive sandstone; while the lower horizons are interbedded massive and thinbedded sandstone and sandy shale. The mineral constituents, including heavy residuals, are quite similar to those of other formations in the St. Croixan series. The mineral contents of the Dresbach differ from those of the overlying formations principally in the absence of glauconitic sand such as is present in the Franconia and St. Lawrence formations. Horizontal variation of the sediments within short distances is characteristic. Horizons in the Dresbach can not be determined by petrographic methods alone.

Every horizon of the Dresbach contains some fossils at some locality. In places it is highly fossiliferous. It carries a distinct and easily recognizable fauna, including brachiopods, trilobites, pteropods, cystoids, and worm borings. Of these the brachiopods are most numerous, but the trilobites are the most reliable guide fossils.

Relations between the Dresbach and the Franconia formations suggest conformity at most places. Nevertheless, there is some evidence of an erosion interval between the deposition of the two formations, and the initial Franconia deposits are believed to be reworked Dresbach sands. Determination of the basal Franconia, particularly by search for the characteristic fauna, is the best method of finding the zone in which the Dresbach-Franconia contact lies. The upper strata of the Dresbach are too variable in character to present features by which they may easily be recognized.

The thickness of the Dresbach is variable. In general it is between 300 and 400 feet, though it is apparently considerably thinner in some localities.

At the surface, the lower limit of the characteristic fauna usually indicates the base of the Dresbach. In wells, the base of the blue shales present in the lower part of the formation is usually taken as the lower limit.

The Dresbach formation of Minnesota has been traced both horizontally and vertically into the "Eau Claire" of Wisconsin. The lack of either a lithological or paleontological break between them makes it evident that they are really but one stratigraphic unit. Although the outcrops in and around Dresbach are at a slightly higher horizon than those in the vicinity of Eau Claire, the similarity of the faunas is too great to warrant separation into two formations. Confusion would be avoided by dropping the name "Eau Claire" for a part of the formation and retaining only the original name—Dresbach, which name should be used only for strata that definitely correlate with those known from the type locality.[65]

[65]The unfossiliferous coarse sandstone of sub-aerial origin referred by Ulrich and others to the Dresbach may or may not be a shore phase and contemporaneous with a part of the true Dresbach of the type area. However, no such deposit is present in the type section. Renaming this sub-aerial deposit would help to avoid confusion.

BIBLIOGRAPHY

Alden, W. C.,
Quaternary geology of southeastern Wisconsin with a chapter on the older rock formations.
U. S. G. S. Professional Paper 106, Chapter 3, 1918.

Anderson, C. B.,
Artesian water of northeastern Illinois.
Ill. State Geol. Survey, Bull. 34, 1919.

Berkey, C. P.,
Geology of the St. Croix Dalles.
Am. Geol. Vol. XX, 1897.
Am. Geol. Vol. XXI, 1898.

Some geologic features of the vicinity of Franconia.
Minn. Acad. Sci. Bull. 4, 1906.

Beyer, S. W., and Williams, I. A.,
Geology of quarry products.
Iowa Geol. Survey, Vol. XVII, 1907.

Billings, E.,
On some new species of Paleozoic fossils.
Journal of Science, Third Series, Vol. III, 1872.

Blanchard, W. O.,
Geography of the Sparta-Tomah quadrangles.
Unpublished thesis on file at the University of Wisconsin, 1917.

Bowles, Oliver,
Structural and ornamental stones of Minnesota.
U. S. G. S. Bull. 663, 1918.

Calvin, S.,
Geology of Allamakee County.
Iowa Geol. Survey, Annual Report, Vol. IV, 1895.

Chamberlin, T. C.,
Geology of Wisconsin, Vol. I, Part 1, 1873-1879.

Diastrophism as the ultimate basis of correlation.
Outlines of Geologic History.—Willis and Salisbury, 1910.

Darton, N. H.,
Central Black Hills.
Geologic Atlas of the United States, Folio 219, 1925.

Grabau, A. W.,
Principles of stratigraphy.
New York, 1913.

A revised classification of the North American lower Paleozoic.
Sci. N. S. 29, 1909.

Grabau, A. W., and Shimer, H. W.,
North American index fossils, invertebrates.
New York, 1909-1910.

Graham, W. A. P.,
A petrographic study of the Cambrian sandstones of Minnesota and Wisconsin.
MS., University of Minnesota, 1927.

Grout, F. F., and Soper, E. K.,
Clays and shales of Minnesota.
U. S. G. S. Bull. 678, 1919.

Hall, C. W.,
Artesian well-boring in southeastern Minnesota.
Bull. Minn. Acad. Nat. Sci., Vol. III, No. 1, 1889.

Hall, C. W., and Sardeson, F. W.,
Paleozoic formations of southeastern Minnesota.
Bull. Geol. Soc. Am., Vol. III, 1892.

Hall, C. W., Meinszer, O. E., and Fuller, M. L.
Geology and underground waters of southern Minnesota.
U. S. G. S. Water Supply Paper 256, 1910.

Hall, James,
Natural history of New York.
Part IV, Geology, 1843.

Preliminary notice of fauna of the Potsdam sandstone; with remarks upon the previously known species of fossils, and descriptions of some new ones, from the sandstone of the Upper Mississippi Valley.
N. Y. State Cabinet, 16th Annual Report, 1863.

Supplementary note on the Potsdam sandstone.
N. Y. State Cabinet, 16th Annual Report, 1863.

Supplementary note on some fossils of the lower beds of the Potsdam sandstone of the Upper Mississippi Valley.
N. Y. State Cabinet, 16th Annual Report, 1863.

On the geologic structure of southern Minnesota.
Canadian Naturalist, Vol. III, New Series, 1868.

Irving, R. D.,
Geology of central Wisconsin.
Geology of Wisconsin, Vol. II, Part III.

Johns, R. B.,
The physiography and geology of the La Crosse River Valley.
Unpublished thesis on file at the University of Wisconsin, 1900.

Keyes, Charles,
Sundry provincial and local phases of general geology.
Proceedings of Iowa Acad. of Science, Vol. XIX, 1912.

Terranal differentiation of Iowa.
Pan-American Geologist, Vol. 38, 1922.

Martin, L.,
Physical geography of Wisconsin.
Wis. Geol. Survey Bull. 36, 1916.

Meeds, A. D.,
The Stillwater deep well.
Bull. Minn. Acad. Nat. Sci., Vol. III, No. 2, 1891.

Miller, S. A.,
North American geology and paleontology.
Cincinnati, 1889.

Nichols, J. T.,
Transition zones.
Science, New Series, Vol. 58, 1923.

Norton, W. H.,
Artesian wells of Iowa.
Iowa Geol. Survey, Annual Report, Vol. VI, 1897.

Underground water resources of Iowa.
Iowa Geol. Survey, Annual Report, Vol. XXI, 1910-1911.

Owen, D. D.,
Geological exploration of part of Iowa, Wisconsin, and Illinois.
Senate Report, 28th Congress, 1840.

Report of a geological reconnaissance of the Chippewa Land District of Wisconsin and the northern part of Iowa.
U. S. 30th Cong., 1st session, S. Ex. Doc. 57, 1848.

Paleontology of the lowest sandstone in the Northwest.
Proc. Am. Assoc. Adv. Sci., Vol. V, 1851.

On a geological map of Wisconsin, Iowa, and Minnesota.
Phil. Acad. Sci., Proc. 6, 1854.

Geological survey of Wisconsin, Iowa, and Minnesota, 1852.

Peterson, Eunice,
Cambrian geology of the lower St. Croix Valley.
Unpublished thesis on file at the University of Minnesota, 1924.

Resser, C. E.,
Bibliographic studies of the Cambrian.
G. S. A. Bull., Vol. 31, 1920.

Sardeson, F. W.,
Type outcrops of Minnesota.
Pan-American Geologist, Vol. XLI, 1924.

Shipton, W. D.,
A new Stratigraphic Horizon in the Cambrian System of Wisconsin.
Proc. Iowa Acad. Sci., Vol. 23, 1917.

Stauffer, C. R.,
The Jordan sandstone.
Journal of Geology, Vol. 33, 1925.

Age of the Red Clastic Series of Minnesota.
G. S. A. Bull., Vol. 38, 1927.

Steidtmann, E.,
Limestones and marls of Wisconsin.
Wis. Geol. and Nat. Hist. Survey, Bull. 66, 1924.

Strong, Moses,
Geology of the Mississippi region north of the Wisconsin River.
Geology of Wisconsin, Vol. IV, 1873-1879.

Teller, E. E.,
A synopsis of the type specimens of fossils from the Paleozoic formations of Wisconsin.
Wis. Nat. Hist. Soc. Bull., Vol. IX, 1911.

Thwaites, F. T.,
The Paleozoic rocks found in deep wells in Wisconsin and Northern Illinois.
Journal of Geology, Vol. 31, 1923.

Tieje, A. J.,
Suggestions as to descriptions and naming sedimentary rocks.
Journal of Geology, Vol. 29, 1921.

Twenhofel, W. H.,
Treatise on sedimentation.
Baltimore, 1926.

Twenhofel, W. H., and Thwaites, F. T.,
Paleozoic section of the Sparta and Tomah quadrangles.
Journal of Geology, Vol. 27, 1919.

Ulrich, E. O.,
Correlation by displacements of the strand-line and function and proper use of fossils in correlation.
Geol. Soc. of Am. Bull., Vol. 27, 1916.

Notes on new names in table formations and on physical evidence of breaks between Paleozoic systems in Wisconsin.
Trans. of Wis. Acad. of Arts, Sci. and Letters, Vol. XXI, 1924.

Upham, Warren,
Notes on rock outcrops in central Minnesota.
Geol. Survey of Minn., 11th Annual Report, 1882.

Walcott, C. D.,
Preliminary studies of the Cambrian faunas of North America.
U. S. G. S. Bull. 10, 1884.

Second contribution to studies of Cambrian faunas of North America.
U. S. G. S. Bull. 30, 1886.

Description of new forms of Upper Cambrian fossils.
Proc. of U. S. Nat. Museum, Vol. XIII, 1890.

Correlation papers—Cambrian.
U. S. G. S. Bull. 81, 1891.

The North American continent during Cambrian times.
U. S. G. S. 12th Annual Report, Part 1, d, 1891.

Geology of the Yellowstone Nat. Park, Cambrian fossils.
U. S. G. S. Monograph 32, Part II, 1899.

New term for the Upper Cambrian Series (Saratogian).
Journal of Geology, Vol. II, 1903.

Cambrian faunas of China.
Proc. U. S. Nat. Museum, Vol. 29, 1905.

Cambrian brachiopods.
U. S. G. S. Monograph 51, 1912.

Dikelocephalus and other genera of the Dikelocephalinae.
Cambrian Geol. and Paleon., Smithsonian Misc. Coll., Vol. 57, No. 13, 1914.

Cambrian trilobites.
Cambrian Geol. and Paleon., Smithsonian Misc. Coll., Vol. 64, No. 3, 1916.

Evolution of early Paleozoic fauna in relation to their environment.
Outlines of Geologic History.—Willis and Salisbury, 1910.

Walter, O. T.,
Trilobites of Iowa and some related Paleozoic forms.
Iowa Geol. Survey, Annual Report, Vol. 31, 1923-24.

Whitfield, R. P.,
Paleontology.
Geology of Wisconsin, Vol. IV, 1873-1879.
Geology of Wisconsin, Vol. I, 1873-1879.

Willis, Bailey,
Paleogeographic maps of North America-Cambrian.
Outlines of Geologic History.—Willis and Salisbury, 1910.

Index to the stratigraphy of North America.
U. S. G. S. Professional Paper 71, 1912.

Wilmarth, M. Grace,
The geologic time classification of the U. S. Geological Survey compared with other classifications.
U. S. G. S. Bull. 769, 1925.

Winchell, Alexander,
Fossils from the Potsdam of Wisconsin and Lake Superior.
Am. Jour. of Sci. and Arts, Vol. 38, 1864.

Report of a geological survey of the vicinity of Belle Plaine, Scott County, Minnesota.
Senate Document, St. Paul, 1872.

Winchell, N. H.,

Geol. and Nat. Hist. of Minnesota, 2nd Annual Report, 1873.

Geological Survey of Minnesota, 10th Annual Report, 1881.

Revision of the stratigraphy of the Cambrian in Minnesota.
Geol. and Nat. Hist. Survey of Minnesota, 14th Annual Report, 1885-1886.

Geol. and Nat. Hist. Survey of Minnesota (Final Report), Vol. I, 1884.

Geol. and Nat. Hist. Survey of Minnesota (Final Report), Vol. II, 1888

Geol. Survey of Minnesota, 22nd Annual Report, 1893.

Wooster, L. C.,
Geology of Lake St. Croix District.
Geology of Wisconsin, Vol. IV, Part 2, 1873-1879.

Zittel, Karl A. von.,
Textbook of paleontology.
Edited by Eastman, C. R., 2nd Edition, London, 1913.

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